FURTHER INVESTIGATIONS OF ASPHALT MODIFIERS

(EFFECTS OF COMMERCIAL MODIFIERS ON THE PHYSICAL PROPERTIES OF MONTANA ASPHALT)

Prepared for the
STATE OF MONTANA
DEPARTMENT OF HIGHWAYS'
RESEARCH PROGRAM

in cooperation with the

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

AUGUST 1989

By

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16. Abstract
During the period of 4-89 to 9-89, asphalts were tested and evaluated in the Asphalt Laboratory at Montana State University. Penetration grade 85-100 asphalts from each of the four Montana refinery sources (Conoco, Exxon, Cenex, and Montana Refining Co.) were combined with paving aggregates, obtained from a Yellowstone River source, to mold Marshall specimens.

Optimum asphalt content, percentage air void, density, Marshall stability and flow at optimum asphalt content for each of the 85-100 unmodified Montana asphalts were determined. The results of these tests were then compared with the results obtained when the same tests were done on modified and unmodified 120-150 asphalts. Evaluation of the test results indicated that the modifiers improved high temperature susceptibility, with variations among the four sources, to levels comparable with the unmodified 85-100 asphalts from the same source.

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DISCLAIMER STATEMENT

The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Montana Department of Highways or of the Federal Highway Administration. This report does not constitute a standard, specification or regulation.

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INTRODUCTION

"Further Investigation of Asphalt Modifiers" is essentially a continuation of the study, "Effects of Commercial Modifiers on the Physical Properties of Montana Asphalt", which was completed on April 1, 1989. In that study, asphalt cements of penetration grade 120/150, from the four Montana refineries, were modified with six commercial modifiers. Physical properties of the modified and unmodified 120/150 asphalts including unmodified 85/100 asphalts were determined in the laboratory, before and after the thin film oven tests. In addition, Marshall specimens were molded and tested for each modified and unmodified 120/150 asphalts.

Results of the testing gave good insight into the changes in temperature susceptibility of the Montana asphalts, which were improved by the modifiers. Strength performance was also enhanced by the modifiers. However, availabile resources did not allow a total testing effort on penetration grade 85/100 asphalts. Only the physical tests on each of 85/100 unmodified Montana asphalts were done. No Marshall testing was done on the 85/100 asphalts.

The idea of asphalt modification is to alter the properties of a softer asphalt (120/150), so that it behaves like a harder asphalt (85/100) during high temperatures; thus rutting is decreased. Therefore, it is desirable to have, at least, the properties of unmodified 85/100 asphalts to compare to modified 120/150 asphalts. The Marshall testing on each of unmodified 85/100 asphalts is performed to obtain a complete data base.

The following section outlines materials, methods and procedures, results and conclusions.

MATERIALS

The 85/100 grade of asphalt obtained from four Montana refineries in 1988 were used in the test. The refineries are Cenex (Laurel), Conoco (Billings), Exxon (Billings) and Montana Refining (Great Falls).

Selection of the aggregate was done after conferring with the MDOH materials personnel in Helena and Billings. Since much of the rutting problems in Montana are in the eastern areas and involve Yellowstone River gravel, a representative of YR gravel was chosen. The Billings District provided material from the E.E. St. John pit (NE 1/4 Sec 31, T5N, R34E). The aggregate conforms to MDOH specification for plant mix grade B and is basically a well graded 3/4 inch minus aggregate (Fig 1). The aggregate plus 1.4% hydrated lime filler was used for the Custer Interchange East project, IR 94-1 (49)47, with 5.3% 85-100 AC by Exxon. Mineral filler was not used in the asphalt-modifier molded specimens. The samples were obtained from stockpiles by MDOH, and submitted in several sacks of three fractions, coarse, crushed fine, and natural fine; a composite sample was formed utilizing 45%, 40%, and 15% portions in accordance with MODH lab reports. Standardization of Marshall procedures required careful attention to representative splitting of the composite sample.

MONTANA STATE UNIVERSITY
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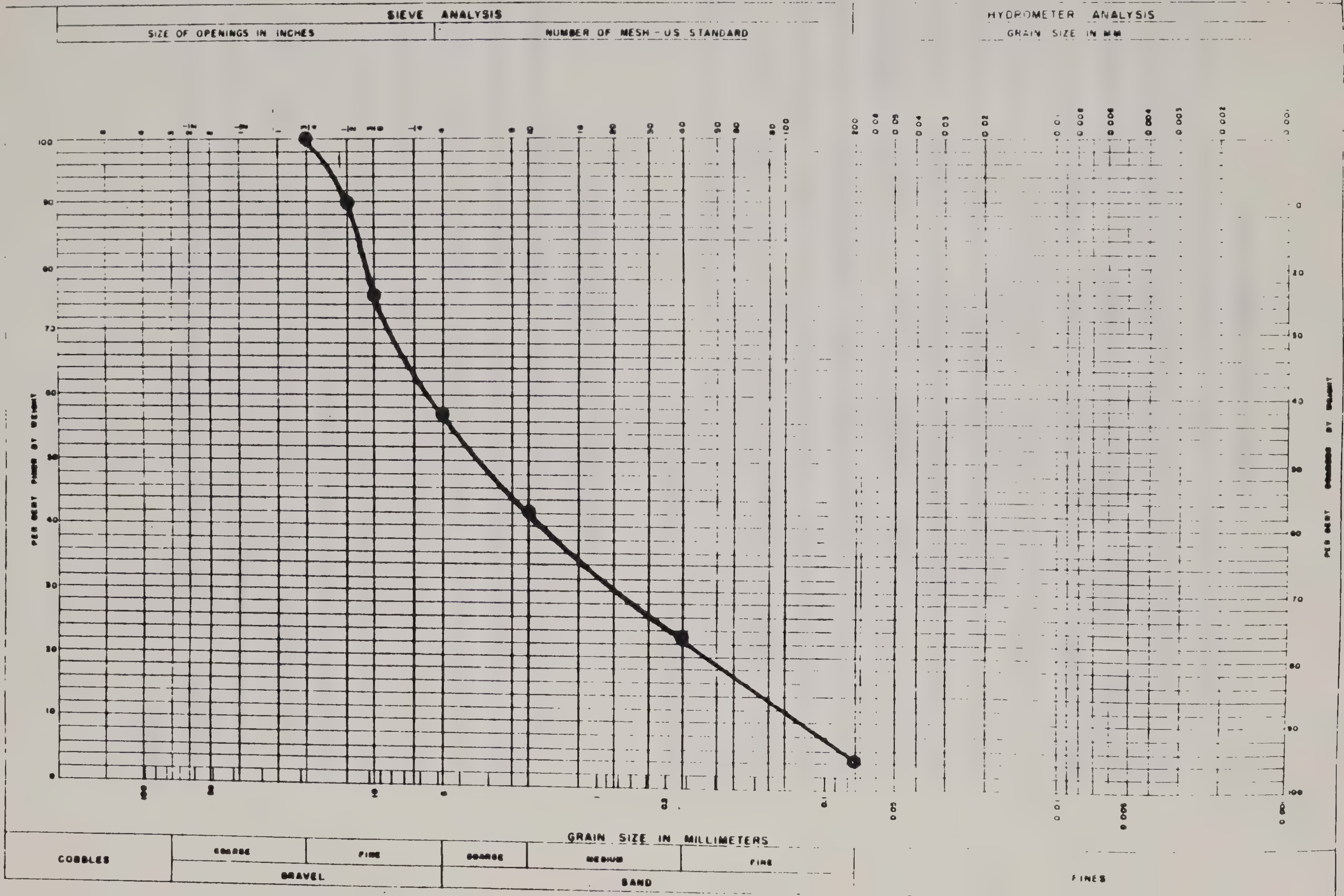
SOIL MECHANICS LABORATORY

Figure 1.

GRADATION CURVE

BY M. Pradhan LABORATORY NO CE Asphalt
DATE 11-5-88, 1-20-89 FIELD NO EE St. John Pit



METHODS AND PROCEDURES

The Marshall test on each of unmodified 85/100 grade Montana asphalt (Cenex, Conoco, Exxon and Montana Refining) was performed. The test procedure as prescribed in the AASHTO method was followed in conducting the Marshall and related tests.

Fifteen Marshall specimens were molded for each of Montana asphalts (three specimens per asphalt content of 5%, 5.5%, 6%, 6.5%, and 7%). The Marshall test for stability and flow, bulk specific gravity , Rice specific gravity and determination of percentage air void were conducted for each specimen. The test results and the test property curves for hot-mix design data by Marshall method is shown in Appendix A. The optimum asphalt content for each of Montana asphalt were computed from the curves and presented in the Table 1.

TEST RESULTS AND OBSERVATIONS

The test results of the optimum asphalt content, percentage air void, density, Marshall stability and flow at optimum asphalt content for each of 85/100 unmodified Montana asphalts are presented in the tabulated form (blocked out) along with the unmodified and unmodified 120/150 asphalt results, thus completing the data base, Tables 2, 3, 4 and 5.

The Figures 2 and 3 demonstrate the relative improvement of the Marshall stability and flow test results respectively of the unmodified 120/150 through modification as compared to 85/100 asphalt.

Table 1. Optimum Asphalt Content for Unmodified 85/100 Asphalt Mix. Data Obtained from Test Property Curves.

Asphalt	Marshall Stability	Marshall Flow	Density	% Air Void @ 4% Aasphalt	Optimum Asphalt
CENEX	7%	5%	7%	6.55%	6.9%
CONOCO	7%	5.5%	6.68%	5.84%	6.5%
EXXON	6.0%	5%	6.0%	6.257%	6.3%
MONTANA REFINING	6.0%	5.5%	6.15%	5.65%	5.9%

Table 2. Data of Unmodified 120/150 Asphalt, Modified 120/150 Asphalts and Unmodified Asphalt 85/100

CENEX Asphalt

Test Description	120/150 Asphalt	Novophalt	Kraton 4463	Kraton 4141 G	Microfil - 8	Polybilt	Ultrapave	85/100 Asphalt
Penetration @ 77 F, dmm	137.0	69.0	121.0	79.0	99.0	91.0	105.0	89.0
Penetration @ 39.2 F, dmm	42.0	29.0	63.0	37.0	37.0	39.0	45.0	24.0
Ring and Ball Softening Pt.	114.8	127.4	149.0	163.4	129.2	133.7	118.4	116.6
Kinematic Viscosity @ 275F	235.8	NA	921.9	1089.2	NA	387.6	452.4	317.9
Absolute Viscosity @ 140F	775.0	NA	NA	NA	NA	1050.9	1718.6	1425.5
Ductility @ 77F, cms.	100.0	21.0	82.5	90.5	100.0	64.5	100.0	100.0
Ductility @ 39.2F, cms	100.0	8.0	4.0	92.0	63.5	11.5	100.0	15.0
After Thin Film Oven Test								
Penetration @ 77 F, dmm	85.0	57.0	89.0	64.0	68.0	59.0	71.0	54.0
Penetration @ 39.2 F, dmm	31.0	24.0	41.0	35.0	28.0	29.0	37.0	28.0
Ring and Ball Softening Pt.	116.5	134.5	156.2	162.5	138.2	137.3	125.6	124.7
Kinematic Viscosity @ 275F	309.3	NA	780.5	1253.8	NA	531.1	518.5	426.0
Absolute Viscosity @ 140F	1501.3	NA	NA	NA	NA	5207.0	2458.4	2851.2
Ductility @ 77F, cms.	100.0	31.5	83.0	86.5	97.0	93.0	100.0	100.0
Ductility @ 39.2F, cms	12.0	4.0	83.0	73.0	10.5	6.0	63.5	NA
Adhesion	80.0	75.0	20.0	90.0	95.0	75.0	85.0	65.0
Optimum Asphalt Content %	5.8	5.7	5.6	5.7	6.0	5.6	6.0	6.9 **
Air Void %	3.0	3.0	3.8	3.8	3.7	3.0	3.0	3.5
Unit Weight	2.387	2.379	2.378	2.37	2.364	2.383	2.385	2.332
Marshall Stability	2400.0	2650.0	2550.0	3500.0	2890.0	2330.0	2370.0	2480.0
Marshall Flow 1/100 Inch.	7.0	7.60	7.80	7.60	6.00	8.20	7.80	6.47

Note:

** Results obtained from further investigations of asphalt modifiers.

Table 3. Data of Unmodified 120/150 Asphalt, Modified 120/150 Asphalts and Unmodified Asphalt 85/100

CONOCO Asphalt

Test Description	120/150 Asphalt	Novophalt	Kraton 4463	Kraton 4141 G	Microfil - 8	Polybilt	Ultrapave	85/100 Asphalt
Penetration @ 77 F, dmm	133.0	60.0	128.0	82.0	106.0	80.0	90.0	92.0
Penetration @ 39.2 F, dmm	40.0	24.0	60.0	36.0	38.0	34.0	36.0	30.0
Ring and Ball Softening Pt.	113.0	134.6	167.0	179.6	136.4	158.9	129.2	120.2
Kinematic Viscosity @ 275F	192.1	NA	650.1	1159.0	NA	388.8	426.0	262.5
Absolute Viscosity @ 140F	549.5	NA	NA	NA	NA	949.2	1390.3	1017.0
Ductility @ 77F, cms.	100.0	28.0	72.0	87.0	75.0	36.5	100.0	100.0
Ductility @ 39.2F, cms	100.0	5.5	100.0	94.0	25.5	9.0	100.0	14.0
After Thin Film Oven Test								
Penetration @ 77 F, dmm	94.0	47.0	98.0	67.0	69.0	62.0	69.0	68.0
Penetration @ 39.2 F, dmm	31.0	30.0	43.0	39.0	30.0	26.0	25.0	19.0
Ring and Ball Softening Pt.	118.4	144.5	174.2	176.9	147.2	149.0	132.8	121.1
Kinematic Viscosity @ 275F	237.1	NA	663.2	1158.4	NA	459.9	487.9	312.1
Absolute Viscosity @ 140F	859.1	NA	NA	NA	NA	1699.6	2262.1	1679.6
Ductility @ 77F, cms.	100.0	33.0	81.0	91.0	69.0	45.0	100.0	100.0
Ductility @ 39.2F, cms	15.0	4.0	85.0	70.0	6.0	5.5	100.0	6.0
Adhesion	90.0	85.0	50.0	85.0	90.0	65.0	85.0	55.0
Optimum Asphalt Content %	5.4	6.0	5.8	5.8	6.0	5.7	6.3	6.5 **
Air Void %	3.6	2.6	2.0	3.0	3.5	3.2	3.6	3.1
Unit Weight	2.308	2.304	2.302	2.373	2.30	2.376	2.342	2.361
Marshall Stability	2060.0	2330.0	2280.0	2410.0	2640.0	2640.0	1910.0	2680.0
Marshall Flow 1/100 Inch.	4.2	8.0	7.0	7.5	5.4	6.8	5.0	6.8

Note:

** Results obtained from further investigations of asphalt modifiers.

Table 4. Data of Unmodified 120/150 Asphalt, Modified 120/150 Asphalts and Unmodified Asphalt 85/100

EXXON Asphalt

Test Description	120/150 Asphalt	Novophalt	Kraton 4463	Kraton 4141 G	Microfil - 8	Polybilt	Ultrapave	85/100 Asphalt
Penetration @ 77 F, dmm	134.0	72.0	119.0	73.0	99.0	84.0	108.0	89.0
Penetration @ 39.2 F, dmm	44.0	27.0	66.0	43.0	43.0	41.0	49.0	27.0
Ring and Ball Softening Pt.	113.0	127.4	136.4	174.2	131.0	136.4	123.8	120.2
Kinematic Viscosity @ 275F	260.5	NA	639.1	1366.1	NA	421.0	508.8	321.3
Absolute Viscosity @ 140F	869.0	NA	NA	NA	NA	1076.3	1947.3	1916.0
Ductility @ 77F, cms.	100.0	69.0	82.5	84.0	100.0	63.5	100.0	100.0
Ductility @ 39.2F, cms	100.0	5.0	100.0	61.5	42.0	10.0	100.0	13.0
After Thin Film Oven Test								
Penetration @ 77 F, dmm	87.0	70.0	103.0	68.0	78.0	64.0	76.0	64.0
Penetration @ 39.2 F, dmm	33.0	27.0	49.0	40.0	38.0	29.0	30.0	24.0
Ring and Ball Softening Pt.	117.5	131.0	165.2	169.7	144.5	143.6	127.4	127.4
Kinematic Viscosity @ 275F	324.5	NA	946.4	1242.1	NA	572.2	580.9	422.9
Absolute Viscosity @ 140F	1609.9	NA	NA	NA	NA	1818.0	3994.5	2919.7
Ductility @ 77F, cms.	100.0	29.0	67.0	73.0	82.0	54.0	100.0	100.0
Ductility @ 39.2F, cms	12.0	5.0	67.0	82.0	8.5	5.5	86.0	6.0
Adhesion	90.0	75.0	80.0	85.0	85.0	75.0	90.0	75.0
Optimum Asphalt Content %	5.8	5.5	5.8	5.9	5.9	5.6	5.9	6.3 **
Air Void %	2.3	3.5	2.5	2.7	3.2	3.0	4.8	3.4
Unit Weight	2.4	2.375	2.363	2.360	2.305	2.375	2.343	2.349
Marshall Stability	2090.0	2320.0	2350.0	3060.0	2550.0	2750.0	1950.0	2730.0
Marshall Flow 1/100 Inch.	9.5	5.0	7.2	7.6	7.5	5.5	5.8	6.2

Note:

** Results obtained from further investigations of asphalt modifiers.

Table 5. Data of Unmodified 120/150 Asphalt, Modified 120/150 Asphalts and Unmodified Asphalt 85/100

MONTANA REFINERY Asphalt

Test Description	120/150 Asphalt	Novophalt	Kraton 4463	Kraton 4141 G	Microfil - 8	Polybilt	Ultrapave	85/100 Asphalt
Penetration @ 77 F, dmm	129.0	59.0	115.0	75.0	89.0	93.0	111.0	87.0
Penetration @ 39.2 F, dmm	32.0	27.0	63.0	42.0	35.0	36.0	48.0	29.0
Ring and Ball Softening Pt.	116.6	127.4	127.4	174.2	127.4	141.8	118.4	122.0
Kinematic Viscosity @ 275F	270.3	NA	570.6	1365.0	NA	437.8	453.6	358.0
Absolute Viscosity @ 140F	826.5	NA	NA	NA	NA	1123.5	1640.3	1481.5
Ductility @ 77F, cms.	100.0	24.0	93.5	86.0	97.5	52.5	100.0	100.0
Ductility @ 39.2F, cms	43.0	4.5	99.0	56.0	12.0	9.0	100.0	7.5
After Thin Film Oven Test								
Penetration @ 77 F, dmm	93.0	53.0	107.0	61.0	68.0	65.0	75.0	52.0
Penetration @ 39.2 F, dmm	29.0	24.0	49.0	36.0	30.0	26.0	26.0	24.0
Ring and Ball Softening Pt.	122.0	136.4	154.4	167.0	138.2	140.0	123.8	127.4
Kinematic Viscosity @ 275F	339.4	NA	779.8	1275.3	NA	500.0	491.3	450.2
Absolute Viscosity @ 140F	1464.7	NA	NA	NA	NA	3522.1	2688.7	2889.1
Ductility @ 77F, cms.	100.0	36.0	85.0	82.0	83.0	53.0	100.0	100.0
Ductility @ 39.2F, cms	8.5	4.0	62.0	62.5	5.0	6.0	100.0	5.0
Adhesion	90.0	75.0	95.0	90.0	85.0	75.0	90.0	80.0
Optimum Asphalt Content %	5.5	5.4	5.5	5.7	5.9	5.5	6.3	** 5.9
Air Void %	3.3	3.5	2.5	2.8	3.7	2.2	3.6	3.4
Unit Weight	2.4	3.366	2.364	3.36	2.39	3.375	2.335	2.368
Marshall Stability	2200.0	2550.0	2340.0	2610.0	2790.0	2510.0	1430.0	2984.0
Marshall Flow 1/100 Inch.	4.4	7.0	5.9	7.4	7.0	7.2	8.7	6.4

Note:

** Results obtained from further investigations of asphalt modifiers.

Figure 1 Marshall Stability Test Data

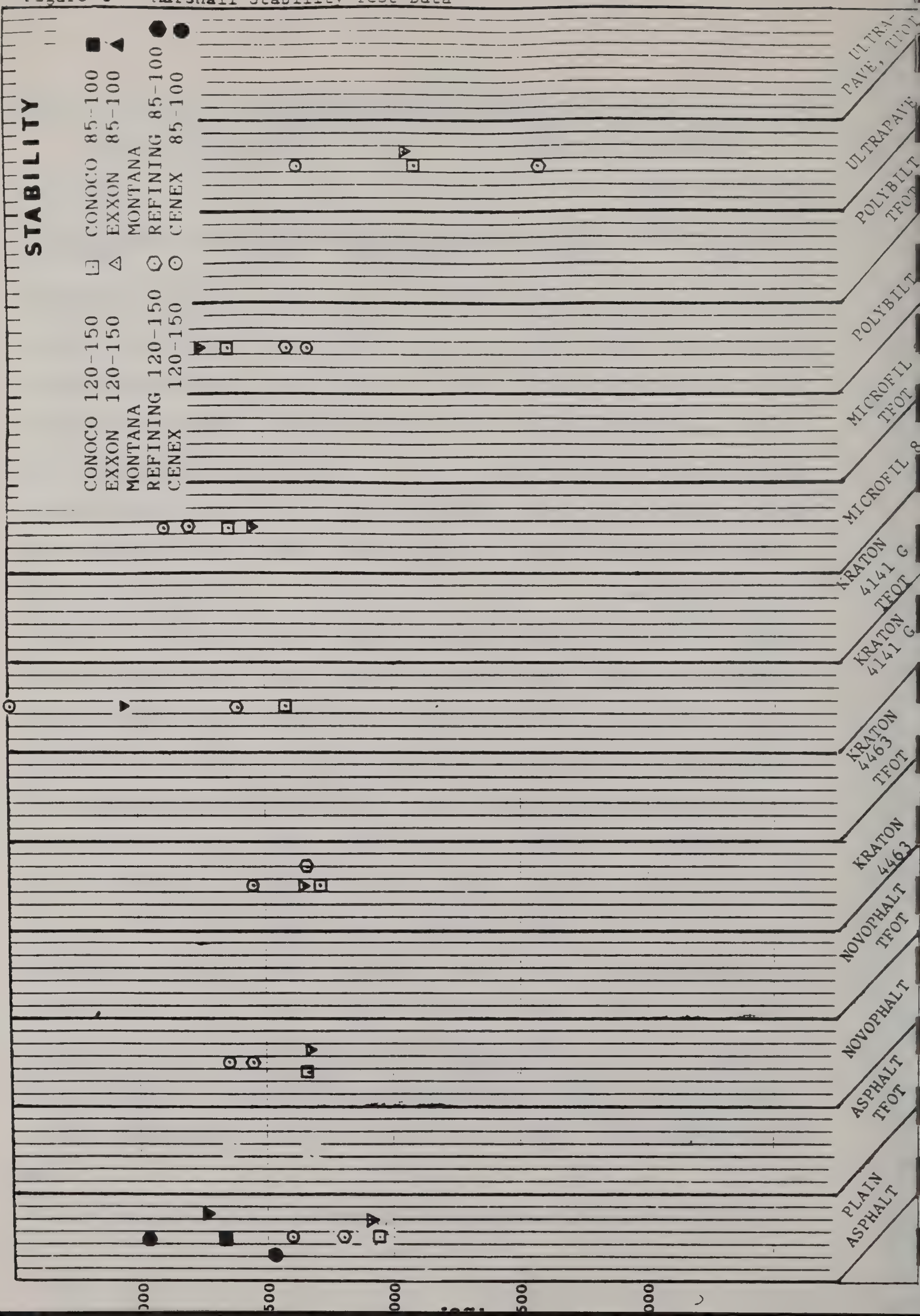
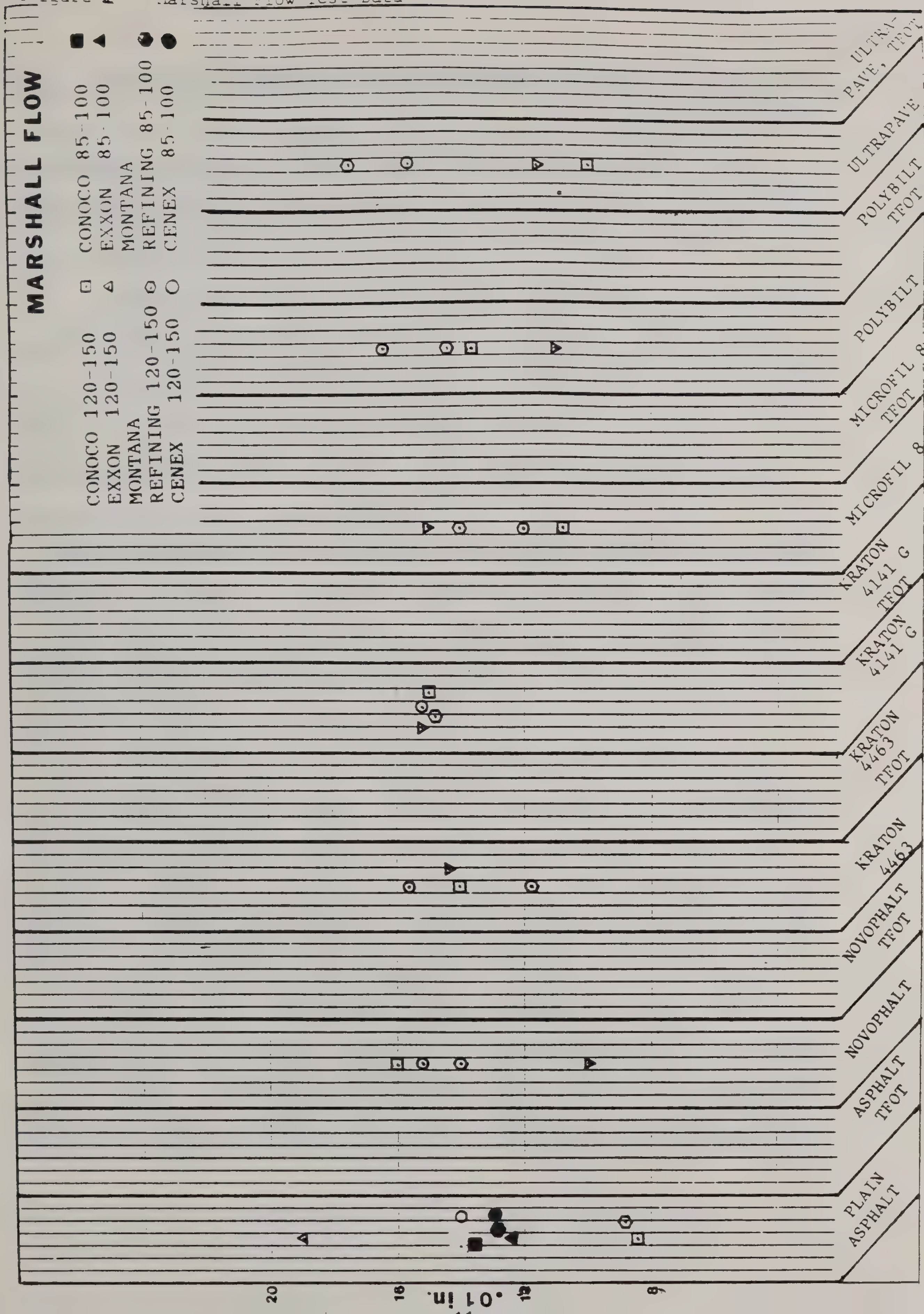


Figure 2 Marshall Flow Test Data



Comparison of the MSU Test Results with Custer Interchange Project Results:

The asphalt used for the Custer Interchange-East Termini was also AC 85/100 grade of Exxon. The aggregate used for the project was also obtained from the same source, E. E. John pit. The comparison of the test results between the Montana State University (MSU) tests and the Montana Department of Highways (MDOH) tests are presented in tabulated form as shown below. The MDOH results were obtained from the Lab. No. G18744, Project No. IR 94-1(49)47. The MDOH test results without asphalt additive (mineral filler) is used for comparison.

Table 6. Comparison of MSU Test Results with MDOH Test Results.

Percent Asphalt		Rice Specific Gravity		Density (gm/cc)		Percent Air Void		Marshall Stability		Marshall Flow	
MSU	MDOH	MSU	MDOH	MSU	MDOH	MSU	MDOH	MSU	MDOH	MSU	MDOH
5.0	5.0	2.474	2.474	2.319	2.334	6.3	5.7	2622	1638	10.5	9
5.5	5.5	2.462	2.457	2.334	2.368	5.2	3.6	2609	2015	10.7	11
6.0	6.0	2.440	2.440	2.343	2.373	4.0	2.7	2787	2132	11.6	11
6.5	6.5	2.428	2.423	2.351	NA	3.2	NA	2676	NA	13.0	NA
7.0	7.0	2.412	2.406	2.351	NA	2.6	NA	2453	NA	14.7	NA

It is observed from the above comparison that Marshall stability is increasing upto 6% asphalt content in both the MSU and MDOH results. Similarly, density is increasing upto 6% asphalt content and beyond in the case of MSU results. The 4% air

void is achieved between 5.0 and 5.5% in case of MDOH and at 6.0% in the case of MSU results. If the optimum asphalt content is to be calculated from the above data, it will be found at close to 6.0% asphalt content. The conclusion derived will be same from both the results.

However, the absolute value of the Marshall stability of the MSU results is much higher. The Rice specific gravity results are almost same in both MSU and MDOH results. The MDOH density results are higher compared to that of MSU.

Comparison of 85/100 Asphalt Test Results with Modified and Unmodified 120/150 Test Results:

The comparison of the test parameters of 85/100 unmodified asphalt and modified 120/150 asphalt with 120/150 unmodified asphalt in percentage difference with respect to unmodified 120/150 asphalt are presented in Tables 7, 8, 9 and 10 (blocked out data obtained in further test).

Since the idea of the asphalt modification is to alter a soft asphalt in the higher temperature ranges, while maintaining low temperature properties, a comparison to unmodified 85/100 asphalt should add insight. The comparisons that follow will involve data from the previous study, as well as the Marshall data for AC 85/100 of this report.

Assume that an area, which has been using AC 120/150, has experienced rutting problems. The conventional solution to the problem would be to switch to AC 85/100. Table 7, for example, tells you that switching to 85/100 would cause an increase in

Table 7. Comparison of Test Parameters of 85/100 Asphalt & Modified 120/150 Asphalts

in % Difference With Respect to Unmodified Asphalt 120/150

CENEX Asphalt

Test Description	85/100 Asphalt	Novophalt	Kraton 4463	Kraton 4141 G	Microfil - 8	Polybilt	Ultrapave
Penetration @ 77 F, dmm	-35.04	-49.64	-11.68	-42.34	-27.74	-33.58	-23.36
Penetration @ 39.2 F, dmm	-42.86	-30.95	50.00	-11.90	-11.90	-7.14	7.14
Ring and Ball Softening Pt.	1.57	10.98	29.79	42.33	12.54	16.46	3.14
Kinematic Viscosity @ 275F	34.82	NA	290.97	361.92	NA	64.38	91.86
Absolute Viscosity @ 140F	83.94	NA	NA	NA	NA	35.60	121.75
Ductility @ 77F, cms.	0.00	-79.00	-17.50	-9.50	0.00	-35.50	0.00
Ductility @ 39.2F, cms	-85.00	-92.00	-96.00	-8.00	-36.50	-88.50	0.00
After Thin Film Oven Test							
Penetration @ 77 F, dmm	-36.47	A* -32.94	F* 4.71	C* -24.71	D* -20.00	B* -30.59	E* -16.47
Penetration @ 39.2 F, dmm	-35.48	E* -22.58	F* 32.26	C* 12.90	B* -9.68	A* -6.45	D* 19.35
Ring and Ball Softening Pt.	7.04	E* 15.45	B* 34.00	A* 39.48	C* 18.63	D* 17.85	F* 7.81
Kinematic Viscosity @ 275F	37.72	NA	B* 152.34	A* 305.37	NA	C* 71.71	D* 67.64
Absolute Viscosity @ 140F	89.92	NA	NA	NA	NA	246.83	63.75
Ductility @ 77F, cms.	0.00	A* -60.50	B* -17.00	C* -13.50	E* -3.00	D* -7.00	F* 0.00
Ductility @ 39.2F, cms	NA	C* -66.67	F* 591.67	E* 500.33	A* -12.50	B* -50.00	D* 429.17
Adhesion	-18.75	E* -6.25	F* -75.00	B* 12.50	A* 18.75	D* -6.25	C* 6.25
Optimum Asphalt Content %	** 18.97	B* -1.72	A* -3.45	B* -1.72	C* 3.45	A* -3.45	C* 3.45
Air Void %	16.67	A* 0.00	A* 26.67	A* 26.67	A* 23.33	A* 0.00	A* 0.00
Unit Weight	-2.30	-0.34	-0.30	-0.71	-0.96	-0.17	-0.00
Marshall Stability	3.33	C* 10.42	D* 6.25	A* 45.83	B* 20.42	F* -2.92	E* -1.25
Marshall Flow 1/100 Inch.	-7.57	B* 8.57	C* 11.43	B* 8.57	A* -14.29	D* 17.14	C* 11.43

Note:

Negative % Difference = Decrease in value
Positive % difference = Increase in value
With Respect To 120/150 Unmodified Asphalt value
* Letter refers to rating - see discussion
** Results obtained from further investigations of asphalt modifiers.

Table 8. Comparison of Test Parameters of 85/100 Asphalt & Modified 120/150 Asphalts

in % Difference With Respect to Unmodified Asphalt 120/150

CONOCO Asphalt

Test Description	85/100 Asphalt	Novophalt	Kraton 4463	Kraton 4141 G	Microfil - 8	Polybilt	Ultrapave
Penetration @ 77 F, dmm	-30.83	-54.89	-3.76	-38.35	-20.30	-39.85	-32.33
Penetration @ 39.2 F, dmm	-25.00	-40.00	50.00	-10.00	-5.00	-15.00	-10.00
Ring and Ball Softening Pt.	6.37	19.12	47.79	58.94	20.71	40.62	14.34
Kinematic Viscosity @ 275F	36.65	NA	238.42	503.33	NA	102.39	121.76
Absolute Viscosity @ 140F	85.08	NA	NA	NA	NA	72.74	153.01
Ductility @ 77F, cms.	0.00	-72.00	-28.00	-13.00	-25.00	-63.50	0.00
Ductility @ 39.2F, cms	-86.00	-94.50	0.00	-6.00	-74.50	-91.00	0.00
After Thin Film Oven Test							
		A*		C*	D*	B*	B*
Penetration @ 77 F, dmm	-27.66	-50.00	4.26	-20.72	-26.60	-34.04	-26.60
		A*		D*	A*	B*	C*
Penetration @ 39.2 F, dmm	-38.71	-3.23	38.71	25.81	-3.23	-16.13	-19.35
		E*	B*	A*	D*	C*	F*
Ring and Ball Softening Pt.	2.20	22.04	47.13	49.41	24.32	25.04	12.16
			B*	A*		D*	C*
Kinematic Viscosity @ 275F	31.63	NA	179.71	300.57	NA	93.97	105.70
Absolute Viscosity @ 140F	95.51	NA	NA	NA	NA	97.83	163.31
		A*	D*	E*	C*	B*	F*
Ductility @ 77F, cms.	0.00	-67.00	-19.00	-9.00	-31.00	-55.00	0.00
		C*	E*	D*	A*	B*	F*
Ductility @ 39.2F, cms	-60.00	-73.33	466.67	366.67	-60.00	-63.33	566.67
		B*	D*	B*	A*	C*	B*
Adhesion	-38.09	-5.56	-44.44	-5.56	0.00	-27.70	-5.56
	**	C*	B*	B*	C*	A*	B*
Optimum Asphalt Content %	20.37	11.11	7.41	7.41	11.11	5.56	16.67
		B*	B*	A*	A*	A*	A*
Air Void %	-13.09	-27.70	-44.44	-16.67	-2.70	-11.11	0.00
Unit Weight	-1.13	-0.17	-0.25	-0.63	-0.34	-0.50	-1.93
		C*	D*	B*	A*	A*	E*
Marshall Stability	30.10	13.11	10.60	17.30	20.16	20.16	-7.20
		F*	D*	E*	B*	C*	A*
Marshall Flow 1/100 Inch.	62.62	90.40	66.67	70.57	20.57	61.90	19.05

Note:
Negative % Difference = Decrease in value
Positive % difference = Increase in value
With Respect To 120/150 Unmodified Asphalt value
* Letter refers to rating - see discussion
** Results obtained from further investigations of asphalt modifiers.

Table 9. Comparison of Test Parameters of 85/100 Asphalt & Modified 120/150 Asphalts

in % Difference With Respect to Unmodified Asphalt 120/150

EXXON Asphalt

Test Description	85/100 Asphalt	Novophalt	Kraton 4463	Kraton 4141 G	Microfil - 8	Polybilt	Ultrapave
Penetration @ 77 F, dmm	-33.58	-46.27	-11.19	-45.52	-26.12	-37.31	-19.40
Penetration @ 39.2 F, dmm	-38.64	-38.64	50.00	-2.27	-2.27	-6.82	11.36
Ring and Ball Softening Pt.	6.37	12.74	20.71	54.16	15.93	20.71	9.56
Kinematic Viscosity @ 275F	23.34	NA	145.34	424.41	NA	61.61	95.32
Absolute Viscosity @ 140F	120.48	NA	NA	NA	NA	23.86	124.09
Ductility @ 77F, cms.	0.00	-31.00	-17.50	-16.00	0.00	-36.50	0.00
Ductility @ 39.2F, cms	-87.00	-95.00	0.00	-38.50	-58.00	-90.00	0.00
After Thin Film Oven Test							
Penetration @ 77 F, dmm	-26.44	C* -19.54	18.39	B* -21.84	E* -10.34	A* -26.44	D* -12.64
Penetration @ 39.2 F, dmm	-27.27	D* -18.18	F* 48.48	E* 21.21	C* 15.15	B* -12.12	A* -9.09
Ring and Ball Softening Pt.	8.43	E* 11.49	B* 40.60	A* 44.43	C* 22.98	D* 22.21	F* 8.43
Kinematic Viscosity @ 275F	30.32	NA	B* 191.65	A* 282.77	NA	D* 76.33	C* 81.48
Absolute Viscosity @ 140F	81.36	NA	NA	NA	NA	12.93	148.12
Ductility @ 77F, cms.	0.00	A* -71.00	C* -33.00	D* -27.00	E* -18.00	B* -46.00	0.00
Ductility @ 39.2F, cms	-50.00	C* -58.33	D* 458.33	E* 583.33	A* -29.17	B* -54.17	F* 616.67
Adhesion	-16.67	D* -16.67	C* -11.11	B* -5.56	B* -5.56	D* -16.67	A* 0.00
Optimum Asphalt Content %	** 8.62	A* -5.17	D* 0.00	C* 1.72	C* 1.72	B* -3.45	C* 1.72
Air Void %	47.83	B* 52.17	B* 8.70	A* 17.39	A* 39.13	A* 30.43	A* 108.70
Unit Weight	-1.63	-0.54	-1.05	-0.84	-0.13	-0.54	-1.88
Marshall Stability	31.00	E* 11.00	D* 12.44	A* 46.41	C* 22.01	B* 31.58	F* -6.70
Marshall Flow 1/100 Inch.	-34.84	A* -47.37	D* -24.21	E* -20.00	B* -21.05	B* -42.11	C* -38.95

Note:
Negative % Difference = Decrease in value
Positive % difference = Increase in value
With Respect To 120/150 Unmodified Asphalt value
* Letter refers to rating - see discussion
** Results obtained from further investigations of asphalt modifiers.

Table 10. Comparison of Test Parameters of 85/100 Asphalt & Modified 120/150 Asphalts

in % Difference With Respect to Unmodified Asphalt 120/150

MONTANA REFINERY Asphalt

Test Description	85/100 Asphalt	Novophalt	Kraton 4463	Kraton 4141 G	Microfil - 8	Polybilt	Ultrapave
Penetration @ 77 F, dmm	-32.56	-54.26	-10.85	-41.86	-31.01	-27.91	-13.95
Penetration @ 39.2 F, dmm	-9.38	-15.63	96.88	31.25	9.38	12.50	50.00
Ring and Ball Softening Pt.	4.63	9.26	9.26	49.40	9.26	21.61	1.54
Kinematic Viscosity @ 275F	32.45	NA	111.10	404.99	NA	61.97	67.81
Absolute Viscosity @ 140F	79.25	NA	NA	NA	NA	35.93	98.46
Ductility @ 77F, cms.	0.00	-76.00	-6.50	-14.00	-2.50	-47.50	0.00
Ductility @ 39.2F, cms	-82.56	-89.53	130.23	30.23	-72.09	-79.07	132.56
After Thin Film Oven Test							
Penetration @ 77 F, dmm	-44.09	A* -43.01	15.05	B* -34.41	D* -26.88	C* -30.11	E* -19.35
Penetration @ 39.2 F, dmm	-17.24	C* -17.24	E* 68.97	D* 24.14	A* 3.45	B* -10.34	B* -10.34
Ring and Ball Softening Pt.	4.43	E* 11.80	B* 26.56	A* 36.89	D* 13.28	C* 14.75	F* 1.48
Kinematic Viscosity @ 275F	32.65	NA	B* 129.76	A* 275.75	NA	C* 47.32	D* 44.76
Absolute Viscosity @ 140F	97.25	NA	NA	NA	NA	140.47	83.57
Ductility @ 77F, cms.	0.00	A* -64.00	E* -15.00	C* -18.00	D* -17.00	B* -47.00	0.00
Ductility @ 39.2F, cms	-41.18	C* -52.94	B* 629.41	E* 635.29	B* -41.18	A* -29.41	1076.47
Adhesion	-11.11	E* -16.67	A* 5.56	B* 0.00	C* -5.56	D* -16.67	B* 0.00
Optimum Asphalt Content %	** 7.27	A* -1.82	B* 0.00	C* 3.64	D* 7.27	B* 0.00	E* 14.55
Air Void %	-4.62	A* 7.69	B* -21.85	B* -13.85	A* 13.85	B* -32.31	A* 10.77
Unit Weight	0.17	42.39	0.00	42.13	1.10	42.77	-1.23
Marshall Stability	35.64	C* 15.91	E* 6.36	B* 10.64	A* 26.82	D* 14.09	F* -35.00
Marshall Flow 1/100 Inch.	45.68	B* 59.09	A* 34.09	D* 68.18	B* 59.09	C* 63.64	E* 97.73

Note:

Negative % Difference = Decrease in value
Positive % difference = Increase in value
With Respect To 120/150 Unmodified Asphalt value
* Letter refers to rating - see discussion

** Results obtained from further investigations of asphalt modifiers.

Marshall stability by only 3.3 percent. On the other hand, electing to switch to a 120/150 AC modified with Kraton 4141G would increase stability by 45.83%, which means Kraton 4141G is a better choice. Another example, unit weight; by switching from 120/150 to 85/100, the density value is brought down by 2.30%, while Polybilt modified 120/150 is able to bring the unit weight value down by 0.17%. (See circled values on Table 7). It is observed from Table 7 that the percentage air void of 85/100 Cenex is greater, by 16.67%, than unmodified 120/150. Similar observation was made in Kraton modified Cenex indicating the need of greater compacting effort to obtain the same percentage air void as that of 120/150 Cenex. This is also confirmed by the decrease in the unit weight. Marshall stability of modified Kraton, Microfil 8 and Novophalt is higher by 46%, 10%, and 20%, respectively, where as that of 85/100 Cenex is greater by only 3% than that of 120/150 unmodified Cenex.

85/100 Conoco and Montana Refining behaved differently from other refineries, Cenex and Exxon. The percentage air void values of 85/100 asphalt and modified 120/150 asphalt are low as compared to that of unmodified 120/150 asphalt. Kraton and Polybilt modified 120/150 asphalt behaved as unmodified 85/100 asphalt as seen from Tables 8 and 10.

Marshall stability of 85/100 Conoco is greater by 30% to that of 120/150 Conoco, similar higher values were noticed in Polybilt, Microfil 8 and Kraton 4141 G modified 120/150 Conoco. Marshall flow of modified Conoco is higher than that of 85/100.

In the case of 85/100 Exxon the percentage air void is higher by 48%, than that of unmodified 120/150 Exxon. Similar higher values are noticed in Microfil 8 and Polybilt indicating the need of greater compacting effort. Marshall stability of Kraton 4141 G and Polybilt modified 120/150 Exxon increased to the level of 85/100 Exxon. The Marshall flow of all modified 120/150 Exxon decreased to the level of 85/100 Exxon.

Similar improvement in the Marshall stability of modified 120/150 Montana Refining is observed but not to the extent of 85/100 Montana Refining. Marshall flow of modified 120/150 Montana Refining increased to the level of 85/100 Montana Refining.

In general, the optimum asphalt content of 85/100 grade asphalt is high relative to 120/150 asphalt.

CONCLUSION

The data base is complete enabling us to compare the result of the Marshall molded specimen tests of the modified 120/150 grade of Montana asphalts with that of the 85/100 grade unmodified asphalts.

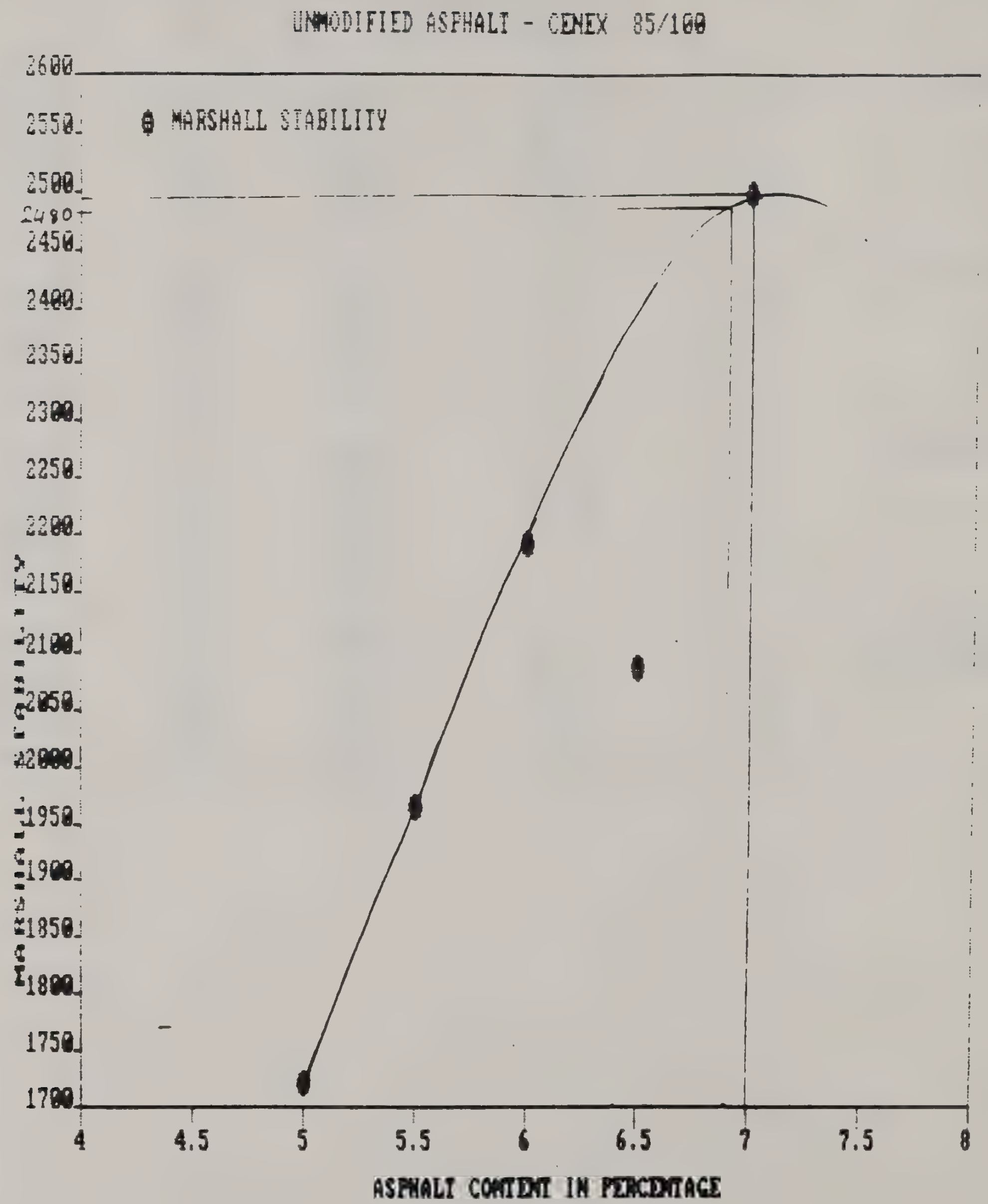
The objective of obtaining the parameter test values of the 120/150 asphalt to the level of 85/100 asphalt through modification is achieved to the greater degree depending on the make of the Montana asphalts. The results of Marshall molded specimen test of the modified Cenex and Exxon are more closer to that of the 85/100 asphalts. Particularly, the Kraton 4141 G, Polybilt and Microfil 8 modified Cenex and Exxon are favorable.

APPENDIX A

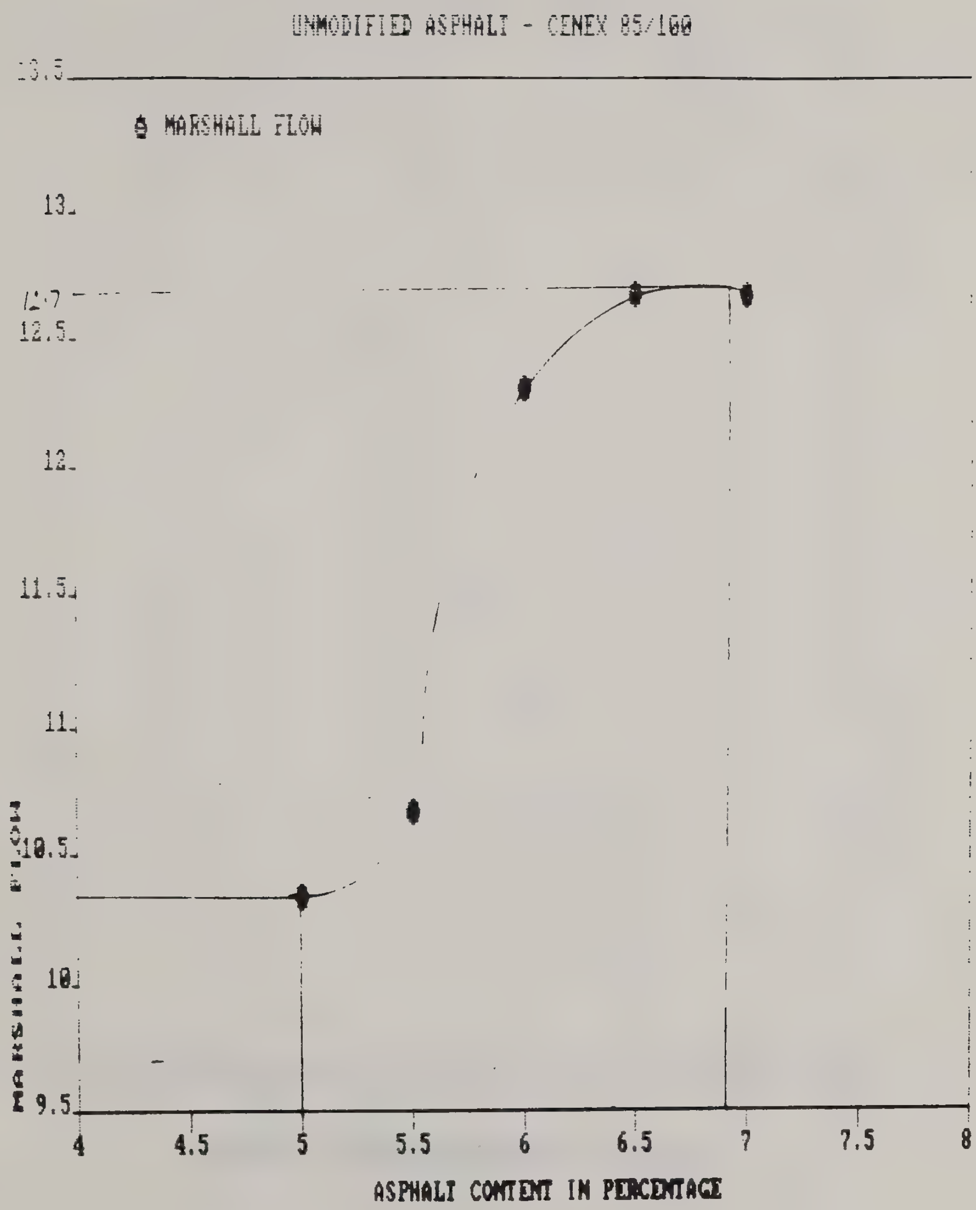
Test Results and the Test Property Curves for Hot-Mix Design Data

Test Results of 85/100 Asphalt.

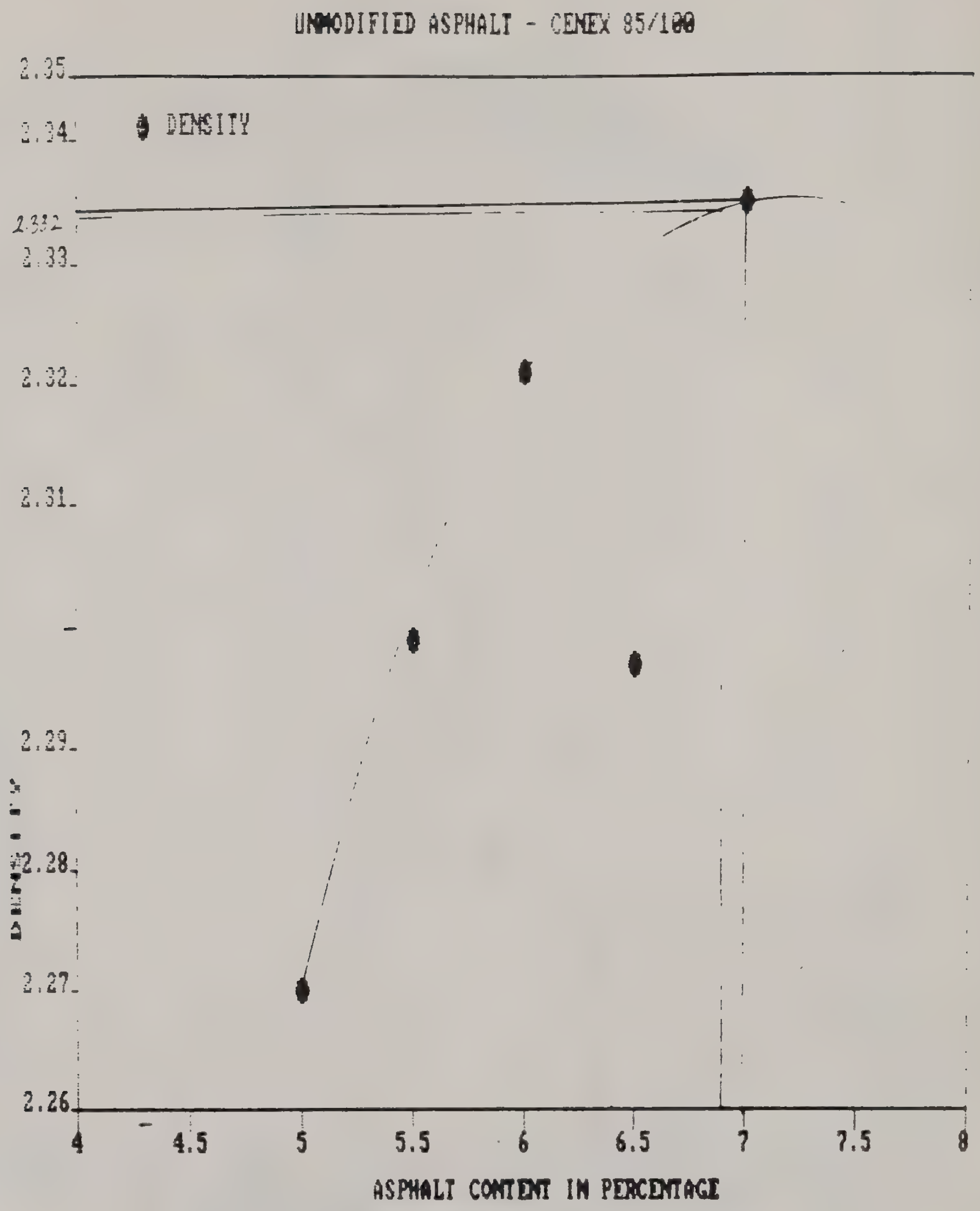
Sample	% Asphalt	Percentage Air Void	Marshall Stability	Marshall Flow	Density
CENEX	5.0	8.51	1721	5.17	2.275
	5.5	6.92	1966	5.30	2.304
	6.0	5.07	2192	6.17	2.326
	6.5	5.92	2087	6.30	2.302
	7.0	3.37	2498	6.50	2.340
CONOCO	5.0	5.57	2477	5.83	2.329
	5.5	5.03	2614	5.50	2.332
	6.0	3.5	2403	5.83	2.362
	6.5	3.1	2628	6.83	2.356
	7.0	2.1	2767	6.33	2.366
EXXON	5.0	6.27	2622	5.25	2.319
	5.5	5.19	2609	5.33	2.334
	6.0	3.96	2787	5.80	2.343
	6.5	3.17	2676	6.50	2.351
	7.0	2.55	2453	7.33	2.351
MONTANA REFINING	5.0	6.62	2887	6.00	2.307
	5.5	5.16	2718	5.67	2.330
	6.0	2.75	2984	6.67	2.371
	6.5	2.57	2449	7.50	2.369
	7.0	2.58	2446	6.50	2.345



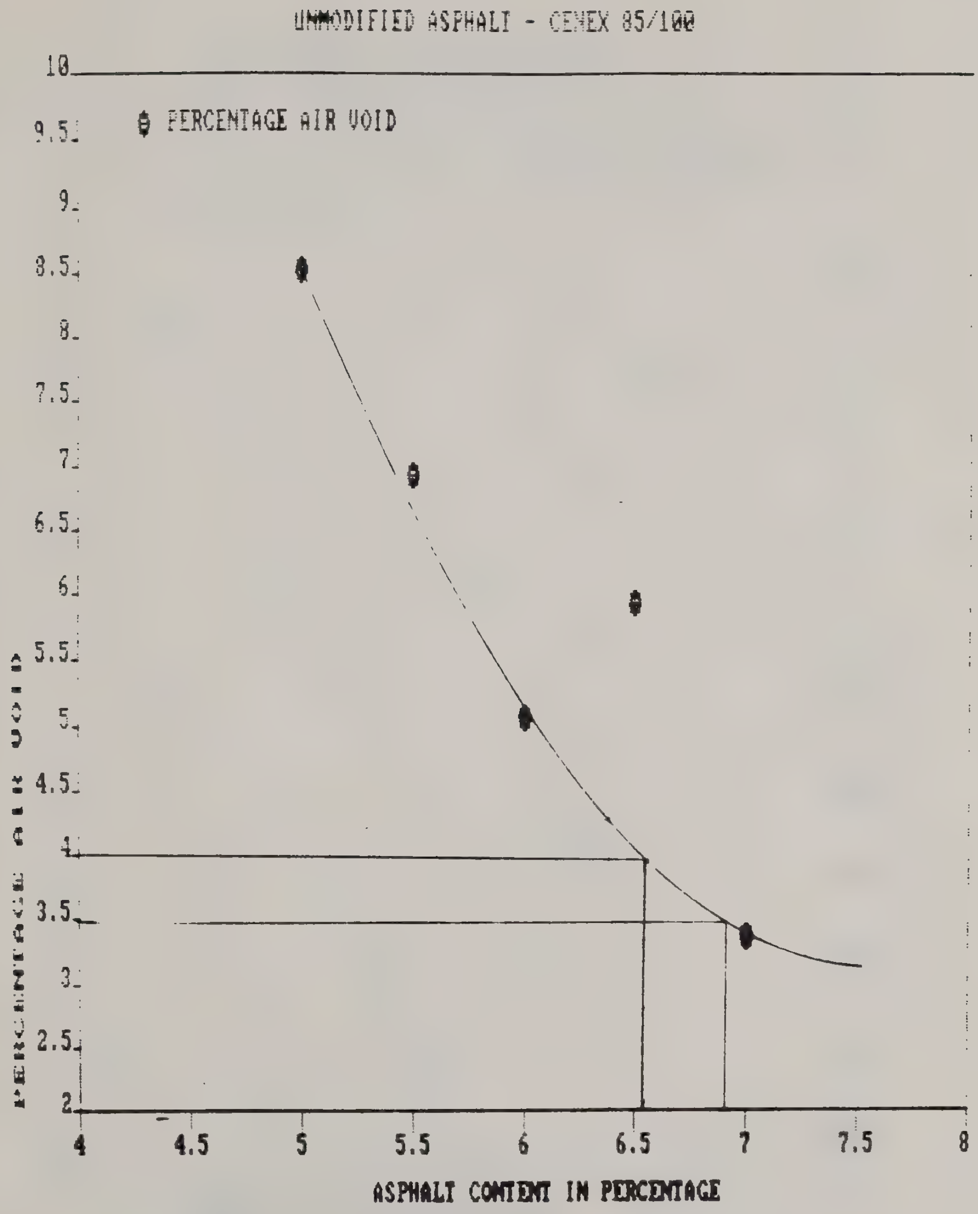
UNMODIFIED ASPHALT - CENEX 85/100
MARSHALL STABILITY
2600
2550
2500
2480
2450
2400
2350
2300
2250
2200
2150
2100
2050
2000
1950
1900
1850
1800
1750
1700
4
4.5
5
5.5
6
6.5
7
7.5
8
ASPHALT CONTENT IN PERCENTAGE

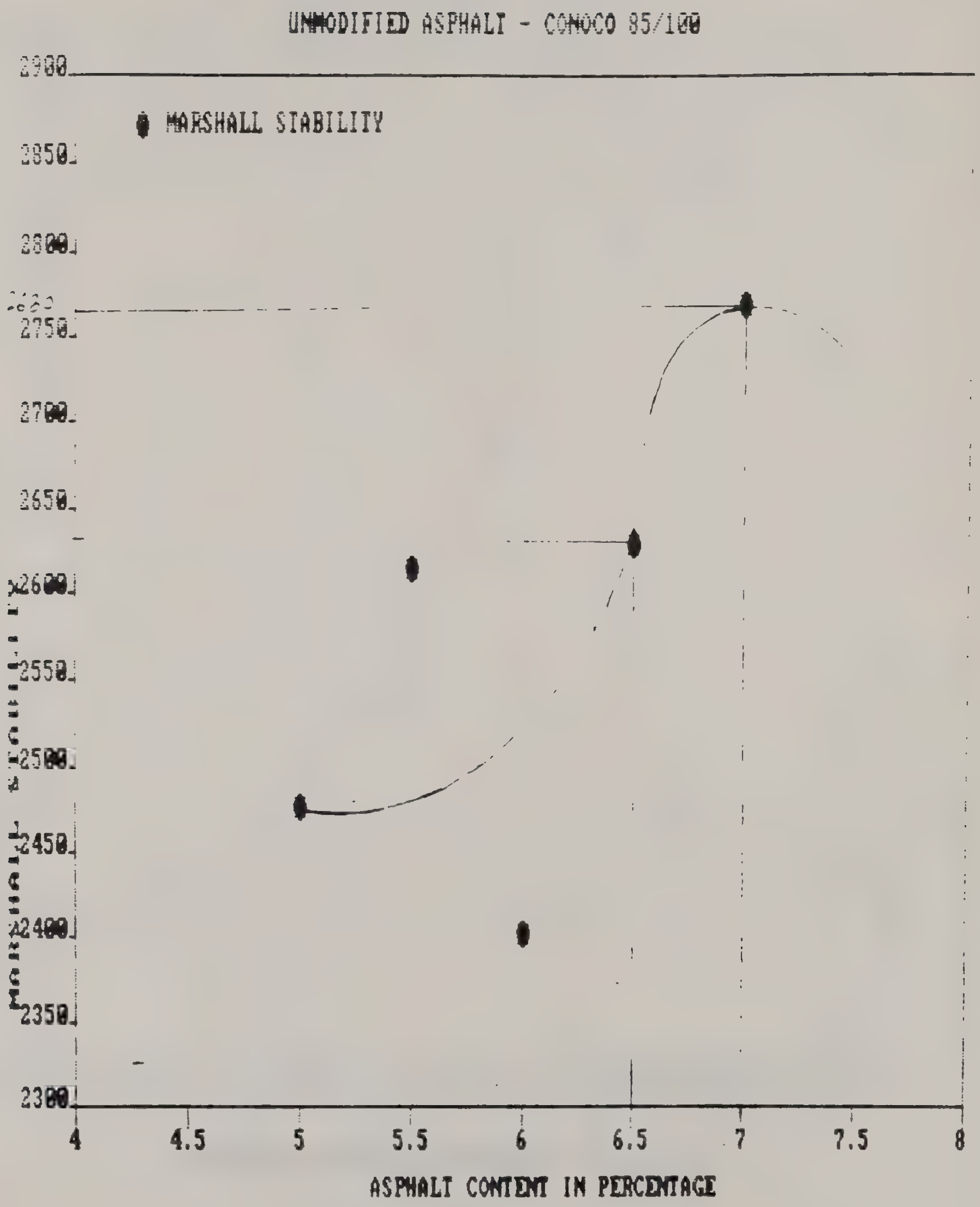


UNMODIFIED ASPHALT - CENEX 85/100
MARSHALL FLOW
13.5
13
12.7
12.5
12
11.5
11
10.5
10
9.5
4
4.5
5
5.5
6
6.5
7
7.5
8
ASPHALT CONTENT IN PERCENTAGE
MARSHALL FLOW

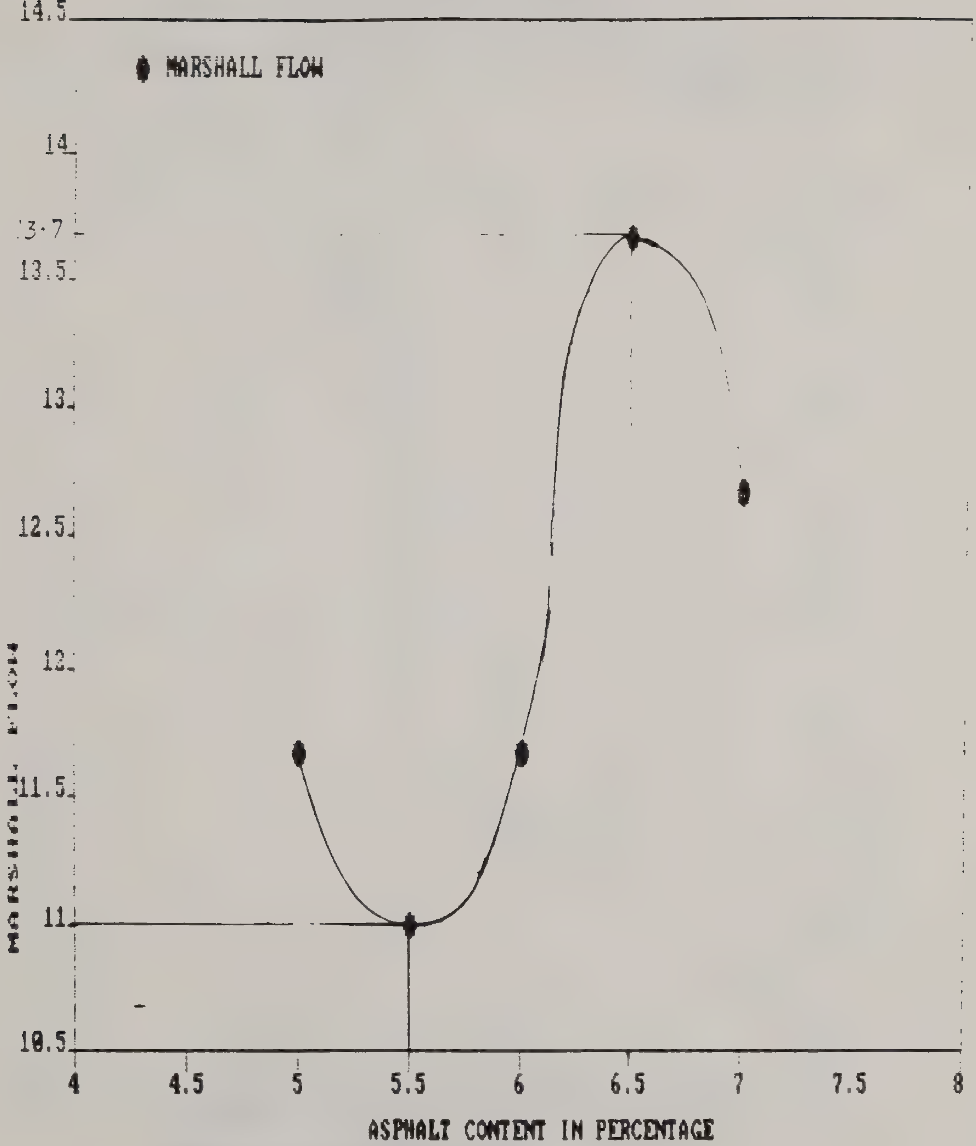


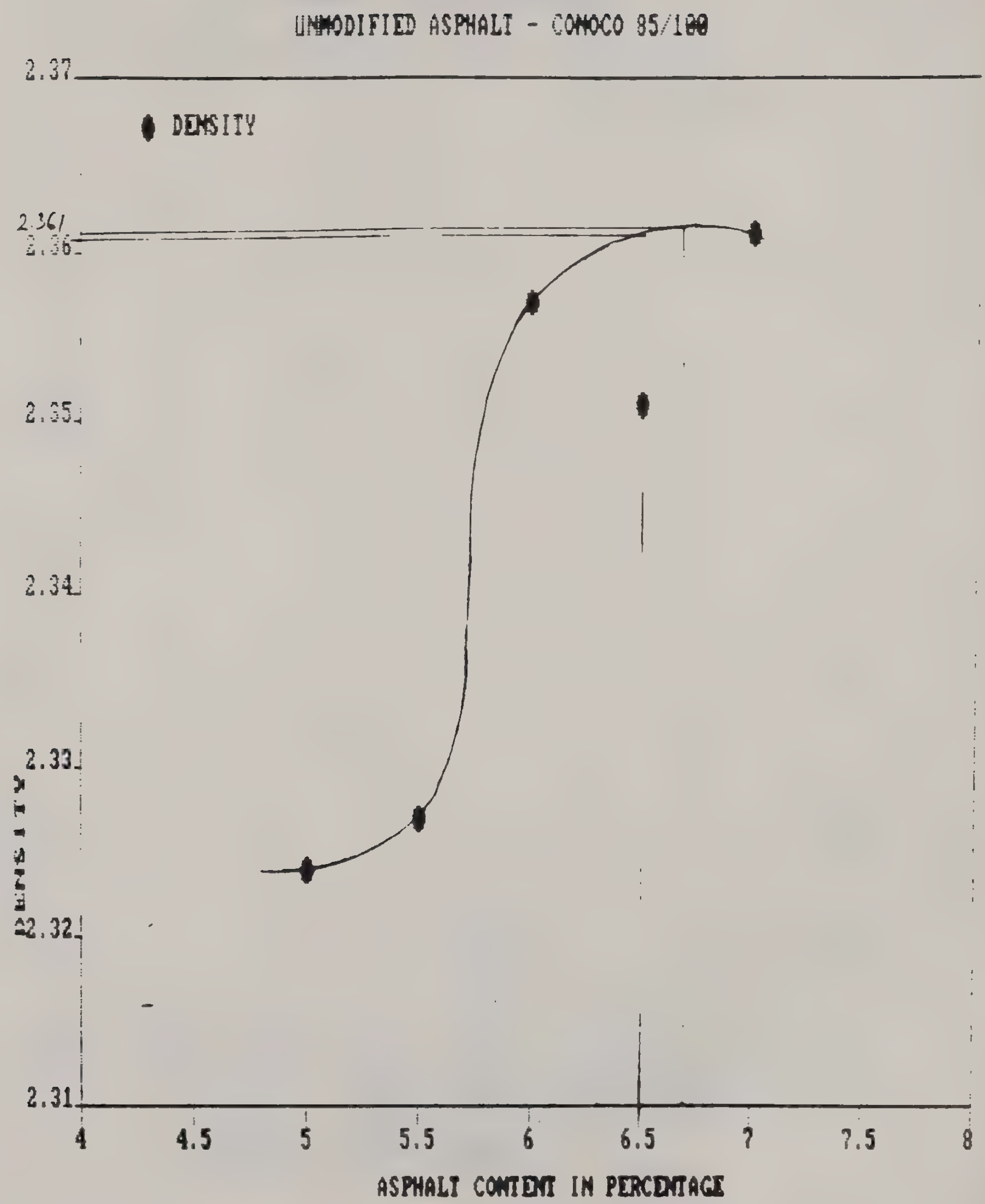
UNMODIFIED ASPHALT - CENEX 85/100
DENSITY
2.35
2.34
2.332
2.33
2.32
2.31
2.29
2.28
2.27
2.26
4
4.5
5
5.5
6
6.5
7
7.5
8
ASPHALT CONTENT IN PERCENTAGE


UNMODIFIED ASPHALT - CENEX 85/100
PERCENTAGE AIR VOID
PERCENTAGE AIR VOID
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
4
4.5
5
5.5
6
6.5
7
7.5
8
ASPHALT CONTENT IN PERCENTAGE

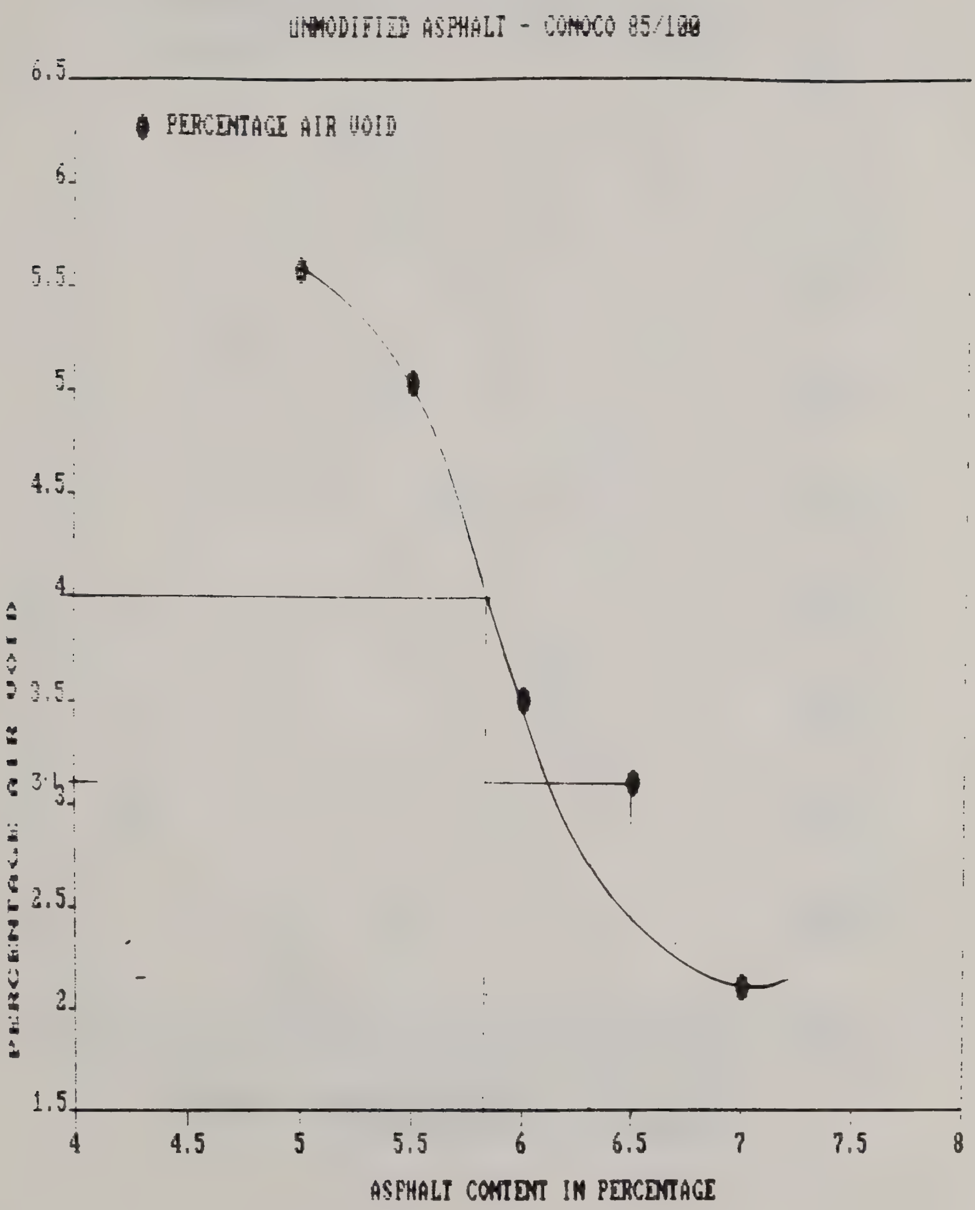

UNMODIFIED ASPHALT - CONOCO 85/100
MARSHALL STABILITY
2900
2850
2800
2750
2700
2650
2600
2550
2500
2450
2400
2350
2300
4
4.5
5
5.5
6
6.5
7
7.5
8
ASPHALT CONTENT IN PERCENTAGE

UNMODIFIED ASPHALT - CONOCO 85/100



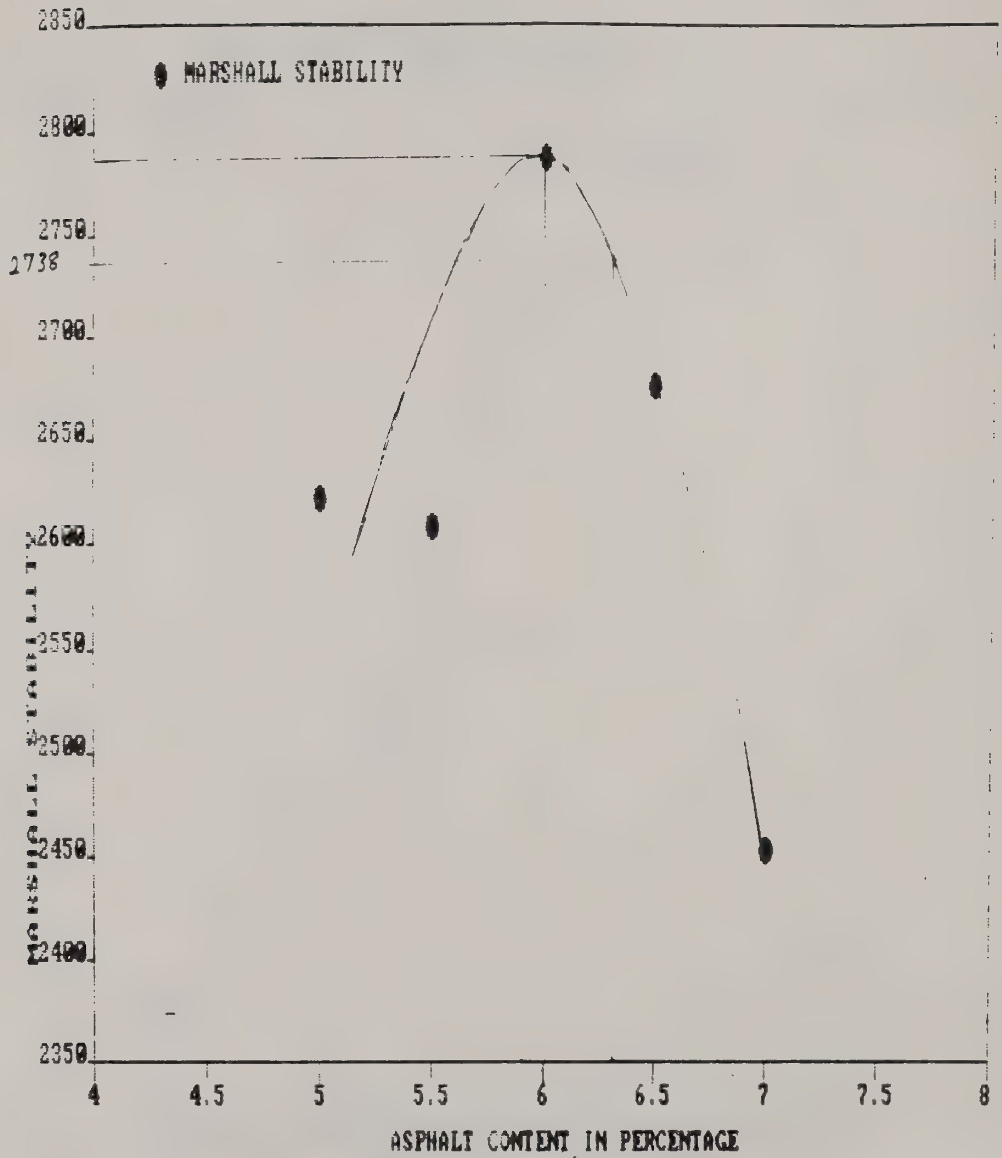


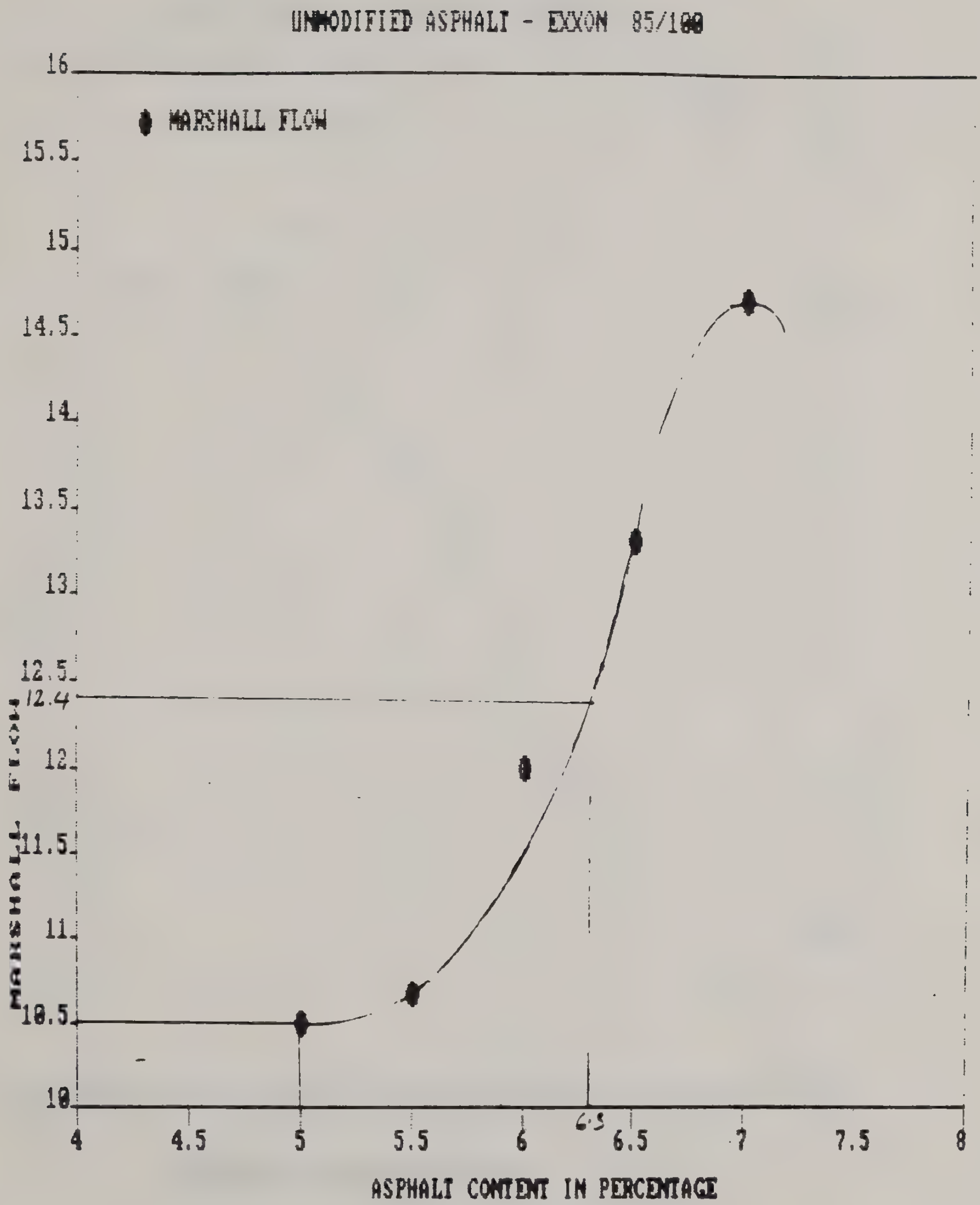
UNMODIFIED ASPHALT - CONOCO 85/100
DENSITY
2.37
2.361
2.36
2.35
2.34
2.33
2.32
2.31
4
4.5
5
5.5
6
6.5
7
7.5
8
ASPHALT CONTENT IN PERCENTAGE

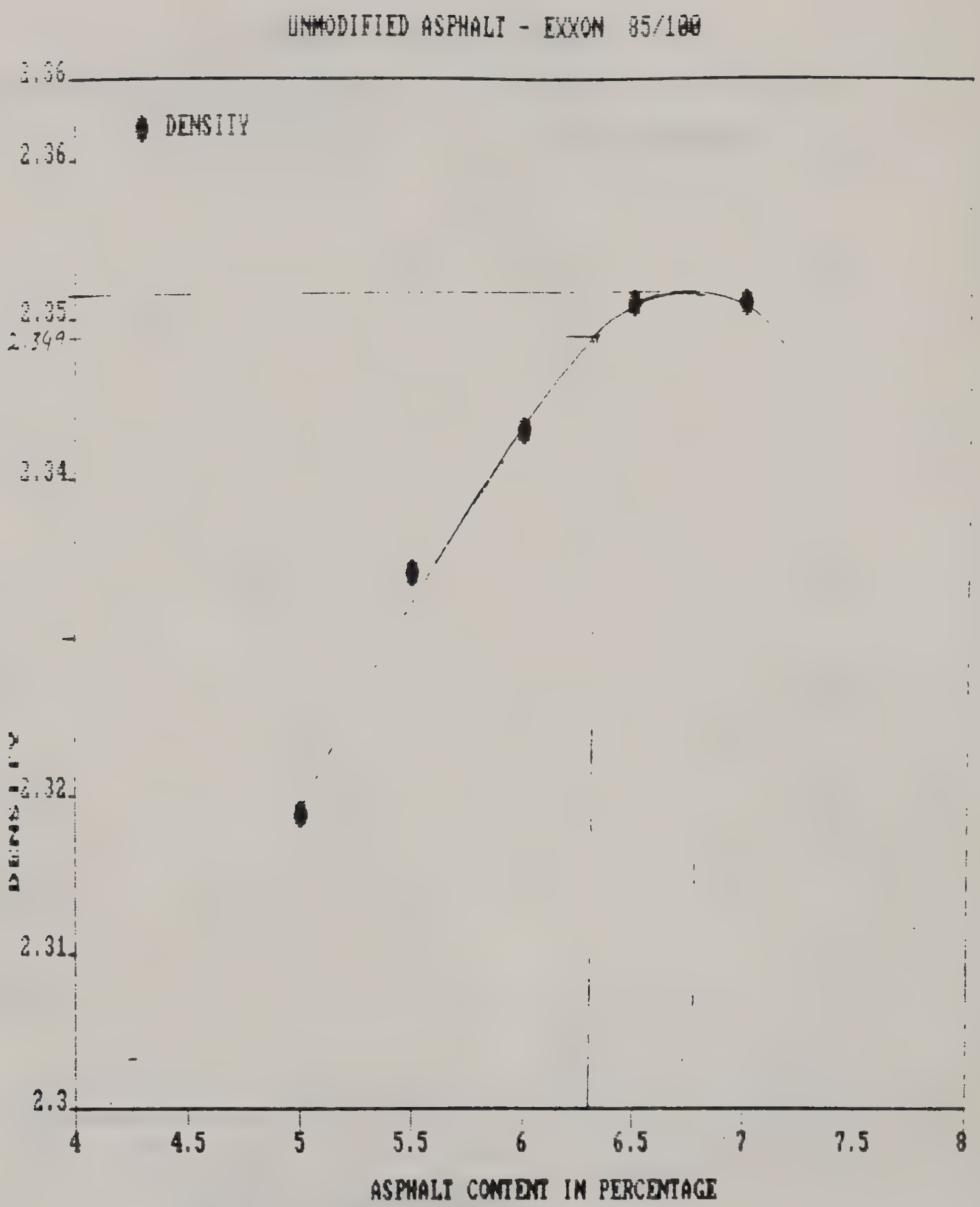


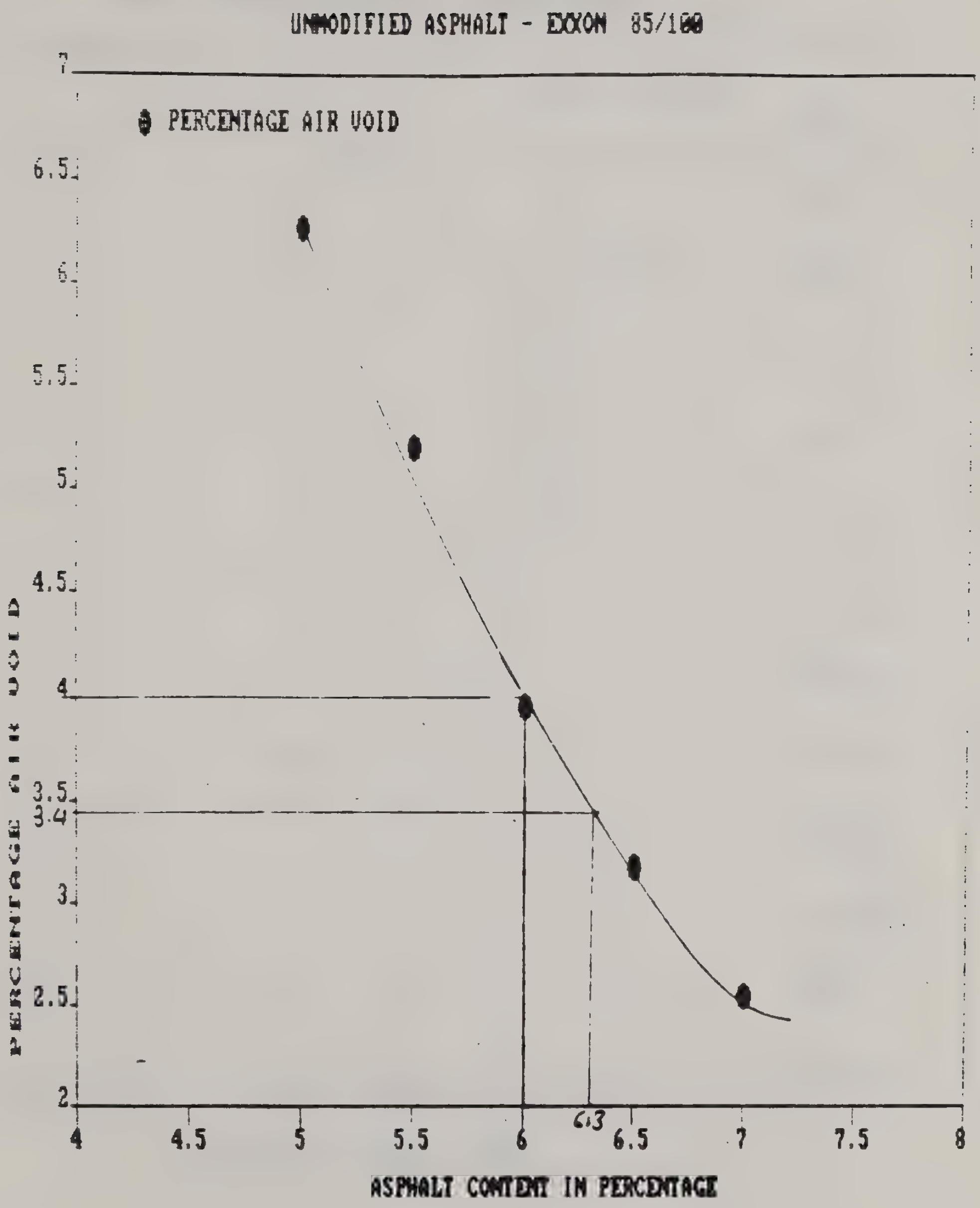
UNMODIFIED ASPHALT - CONOCO 85/100
PERCENTAGE AIR VOID
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
PERCENTAGE AIR VOID
4
4.5
5
5.5
6
6.5
7
7.5
8
ASPHALT CONTENT IN PERCENTAGE

UNMODIFIED ASPHALT - EXXON 85/100

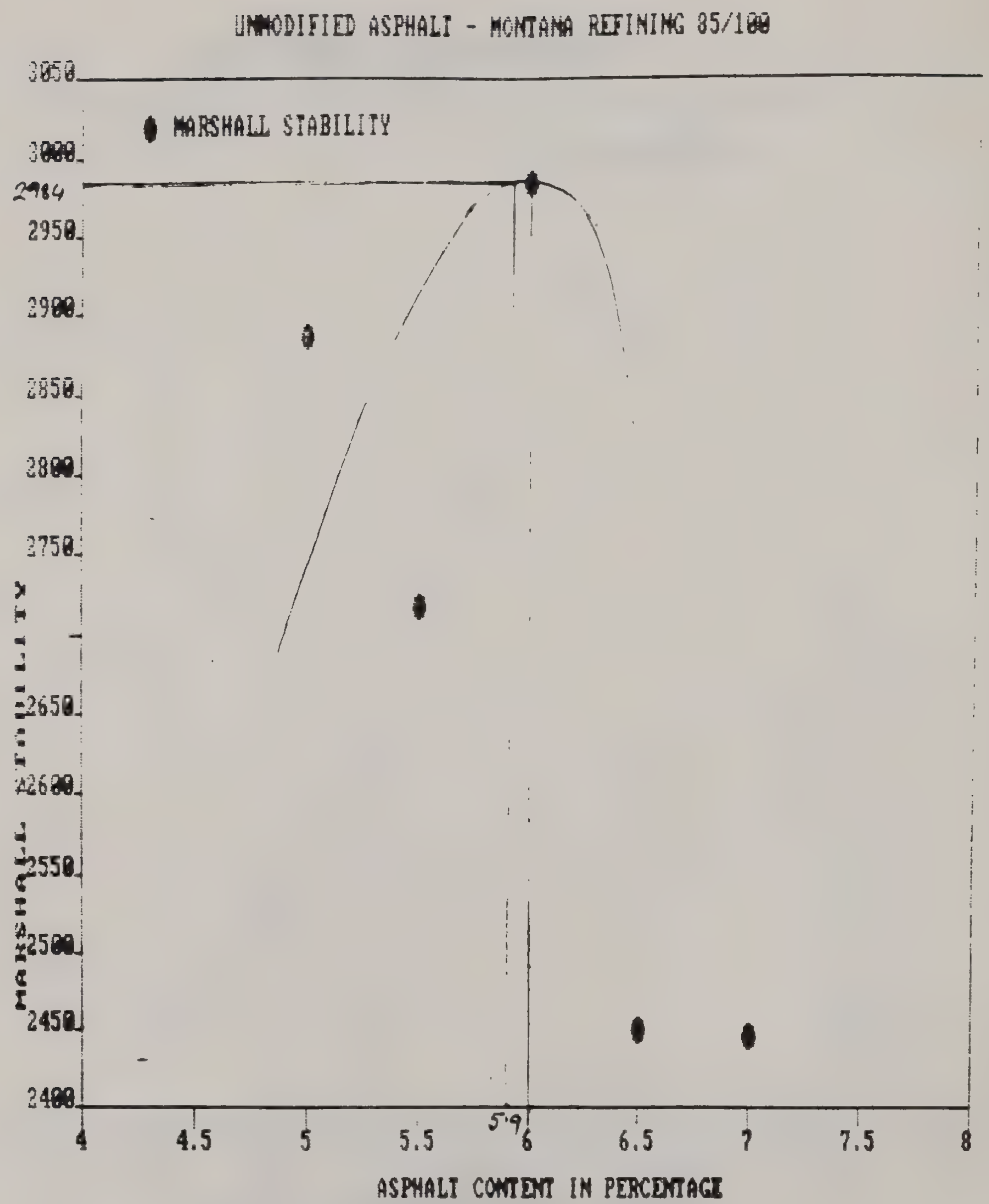



UNMODIFIED ASPHALT - EXXON 85/100
MARSHALL FLOW
16
15.5
15
14.5
14
13.5
13
12.5
12.4
12
11.5
11
10.5
10
4
4.5
5
5.5
6
6.5
7
7.5
8
6.3
ASPHALT CONTENT IN PERCENTAGE
MARSHALL FLOW

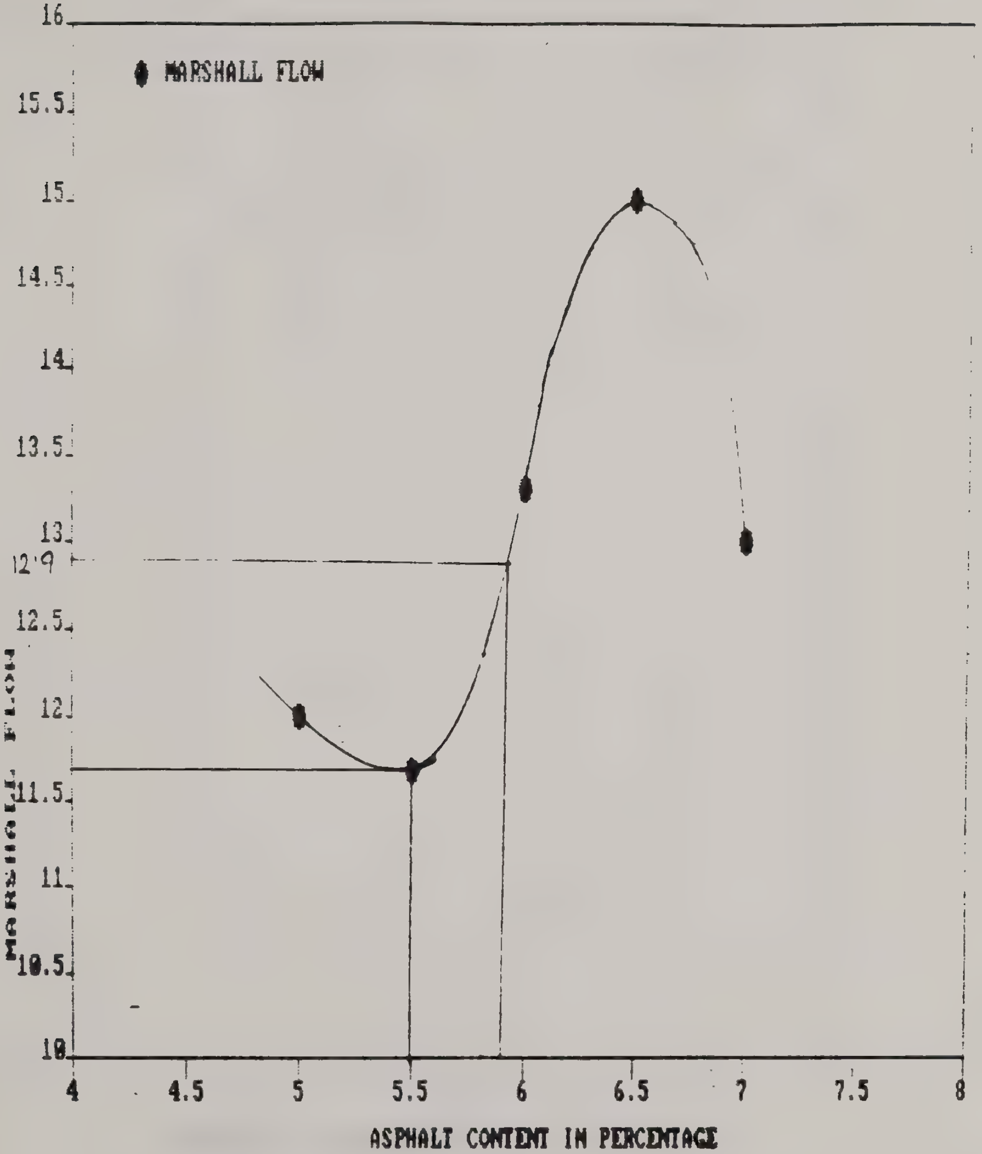

UNMODIFIED ASPHALT - EXXON 85/100
DENSITY
2.36
2.35
2.349
2.34
2.32
2.31
2.3
DENSITY
4
4.5
5
5.5
6
6.5
7
7.5
8
ASPHALT CONTENT IN PERCENTAGE

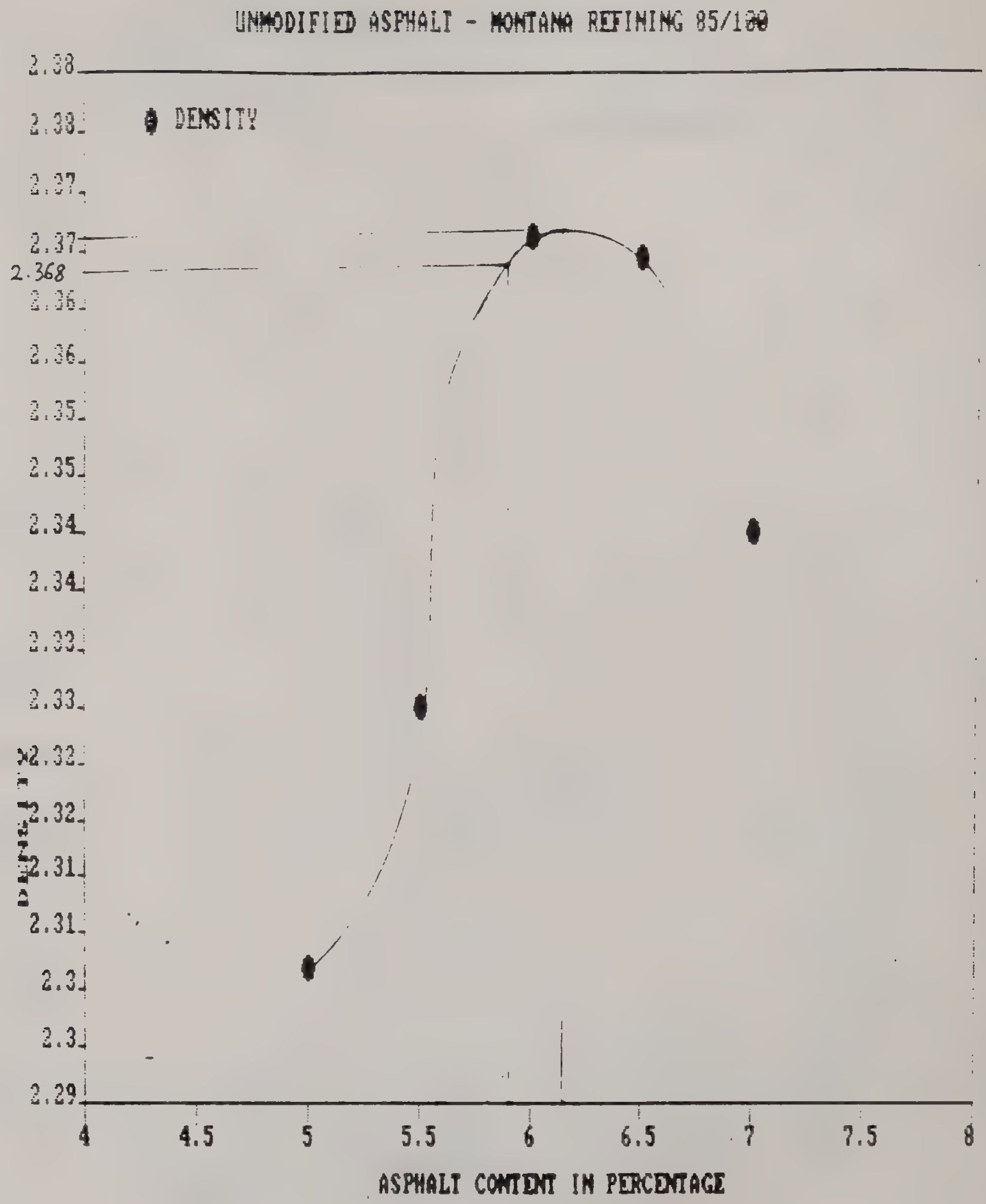


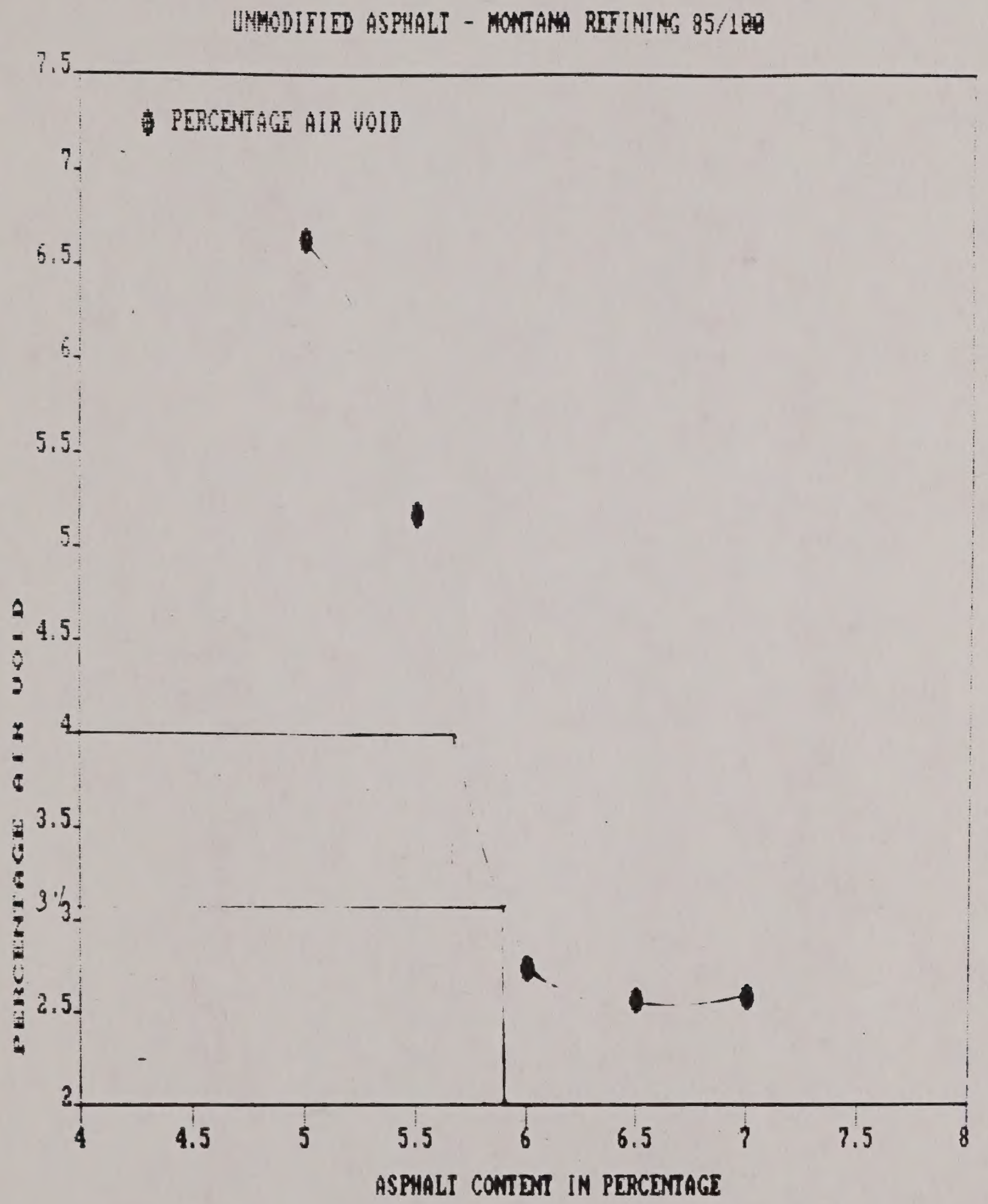
UNMODIFIED ASPHALT - EXXON 85/100
PERCENTAGE AIR VOID
PERCENTAGE AIR VOID
7
6.5
6
5.5
5
4.5
4
3.5
3.4
3
2.5
2
4
4.5
5
5.5
6
6.3
6.5
7
7.5
8
ASPHALT CONTENT IN PERCENTAGE


UNMODIFIED ASPHALT - MONTANA REFINING 85/100
MARSHALL STABILITY
MARSHALL STABILITY
3050
3000
2984
2950
2900
2850
2800
2750
2650
2600
2550
2500
2450
2400
4
4.5
5
5.5
5.9
6
6.5
7
7.5
8
ASPHALT CONTENT IN PERCENTAGE

UNMODIFIED ASPHALT - MONTANA REFINING 85/100




UNMODIFIED ASPHALT - MONTANA REFINING 85/100
DENSITY
2.368
ASPHALT CONTENT IN PERCENTAGE



UNMODIFIED ASPHALT - MONTANA REFINING 85/100
PERCENTAGE AIR VOID
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3 %
3
2.5
2
4
4.5
5
5.5
6
6.5
7
7.5
8
PERCENTAGE AIR VOID
ASPHALT CONTENT IN PERCENTAGE